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Mechanics of Abrasion of Textile Materials

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A method is described for predicting the inherent abrasion resistance of textile materials substantively by the use of load-elongation diagrams of mechanically conditioned specimens. Immediate and delayed deflections are discussed as they affect energy coefficient E. *This coefficient is shown to be a function of: (1) low modulus of elasticity; (2) large immediate elastic deflection; (3) high ratio of primary to secondary creep; (4) high magnitude of primary creep; and (5) high rate of primary creep.*

Nylon shrunk, nylon unshrunk, acetate, and viscose yarns are evaluated on the Taber Abraser, and from rate-of-destruction curves durability coefficients D *are obtained. Correlation is shown to exist between durability coefficients and energy coefficients for the four yarns.*

THE resistance to abrasion by textile materials has been the subject of discussion by investigators over a period of many years. The literature reveals the fact that it is recognized to be a complex phenomenon involving many factors, such as type of fiber, yarn structure, fabric structure, and type of finish. During the past twenty years [1],* at least twenty-five different "wear testing" devices have been described in various technical journals, but in almost every instance the investigations emphasize an evaluation of the resultant destruction of the specimen rather than a determination of the basic cause or causes of failure.

The terminology, as is the case in so many phases of textile technology, is badly confused. "Wear" and "abrasion" are used interchangeably, whereas actually they are not synonymous [2]. Ball [3] comments as follows: " 'Abrasion,' derived from the verb 'to abrade,' very distinctly suggests 'rubbing off' . . . . It is suggested, therefore, that the term 'wear' be considered as of broader scope than 'abrasion,' and be used to apply wherever other important destructive actions, with or without abrasion, are existent."

The term "abrasion" as used in this paper connotes rubbing off or wearing away by attrition and excludes all other destructive influences.

It has been indicated that measuring abrasion resistance is a quantitative method for evaluating the

*Figures in brackets refer to Literature Cited at the end of this paper.

effect of frictional forces on the textile and that such effects should be proportional to the work done on the test sample [3]. While the literature alludes to this energy concept, little if any work has been done with the view to correlating effects with causes. The need of a study of cause and effect is recognized by many technologists. Ashcroft [2] states: "To duplicate wear results, it is first necessary to find out what forces cause wear"; and Smith [4] comments: "I should like to see . . . the causes of wear, . . . and the properties of textiles which affect wearability determined." While, in both cases, the destructive action is characterized as wear, nevertheless abrasion is one of the important contributory factors.

Resistance of a specimen to destruction resulting from stress application may be described as the absorption of energy imparted to the specimen without the occurrence of failure.

Textiles are seldom designed to withstand a single stress application of high magnitude. The conventional fabrics are subjected to long usage, and, during their lifetime, experience a series of repeated stress applications and removals. Bending, tensioning, compressing, and twisting are all such repeated stress applications. Abrasion is definitely a repeated stress application, usually caused by forces of relatively low orders of magnitude which occur many times during the life expectancy of the material. To resist destruction, the specimen must be capable of absorbing energy imparted to it upon stress application and of releasing this energy upon removal of the stress without the occurrence of failure.

Deformation of a material under load is governed by two major components [5]—the immediate elastic deflection and the delayed deflection. The latter component is designated as "creep" and may be divided into two classes: *primary creep,* which is the recoverable portion of the delayed deformation and may be characterized as the delayed elastic deflection; and *secondary creep,* which is the non-recoverable portion and may be characterized as permanent set or plastic flow.

The fundamental physical properties of materials govern their ability to absorb and return energy. Energy absorption capacity is a function of the load-deflection characteristics of the material. If the energy absorbed by a specimen upon load application is to be returned without appreciable loss upon load

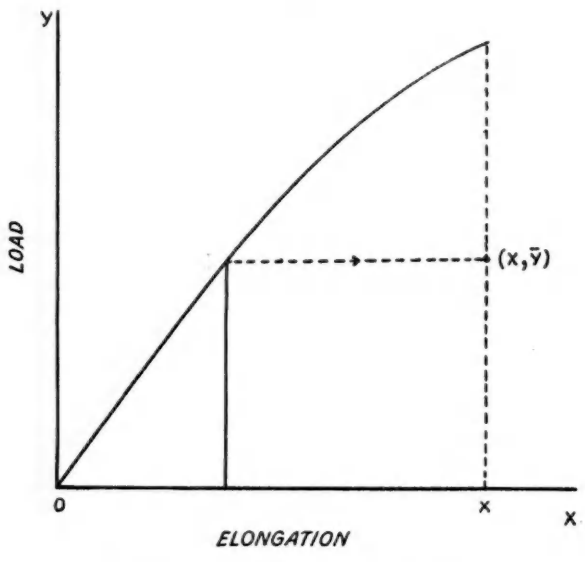

FIG. 1. *Load-elongation curve.*

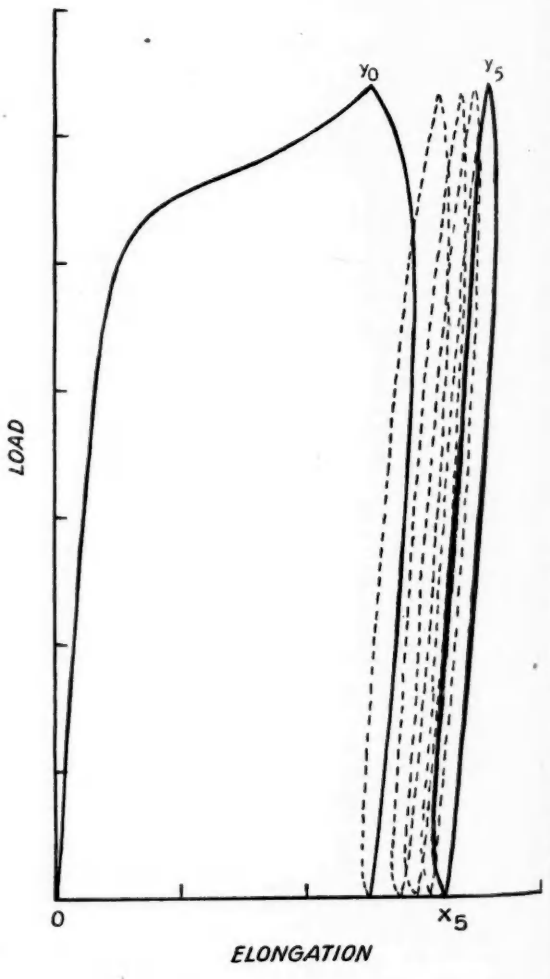

FIG. 2. *Diagram of typical repeated loading curves.*

removal, then the basic requirement is one of elasticity in the classical sense.

In the engineering sense, "perfect elasticity" connotes the ability of a specimen to return completely and immediately to its original form upon removal of the stress. Textile materials are not perfectly elastic in the sense that they do not immediately return to their original form upon load removal. However, they do, under certain circumstances (secondary creep being absent), return completely even though the recovery is delayed [5]. Materials exhibiting this phenomenon may be said to be "completely" elastic.

Energy is work done and may be defined as a function of the average force and the distance through which the force acts. Hence, the primary creep and secondary creep (non-recoverable deflection) as well as the instantaneous elastic deflection all contribute to the energy absorption capacity of a material.

It has been shown [5] that the secondary creep may be removed by means of a relatively few loading and unloading cycles. For a material to resist abrasion, it must withstand many cycles. While secondary creep is an energy-absorbing component of the total deflection, its contribution under repeated loadings is negligible since it is removed in the course of the first few cycles. Both the immediate elastic deflection and the creep deflection are recoverable upon load removal. They contribute both to the absorption and the return of energy necessary for proper performance under repeated stress, the contribution of the creep deflection being dependent upon the rate of primary creep and the time intervals between stress cycles.

Energy may be graphically represented as the area under a load-deflection curve. If, then, the load-deflection curve is constructed for a material subjected to a tensile loading, the area under the curve is a manifestation of the energy expended by the testing machine in straining the specimen. This energy may also be considered as having been absorbed by the specimen. It is obvious that, all other factors being equal, a large deflection at a given load will yield a greater energy. Thus, a low modulus of elasticity is desirable.

Textile materials do not have a

TABLE I. ABRASION RATE CURVES (FIGURE 3)
Percent Loss in Strength

Cycles	Acetate	Viscose
0.0	0.0	0.0
10	12.1	16.3
25	20.0	21.4
50	26.3	25.7
100	35.1	30.7
150	37.1	32.7
200	39.1	36.9
250	39.8	39.2
300	41.3	43.2
350	43.3	45.5
400	46.6	48.5
450	47.1	50.2
500	52.6	53.2
750	60.9	70.0
1000	80.7	86.6
1100	92.2	93.4
1120	100.0	—
1200	—	100.0

Cycles	Unshrunk Nylon	Shrunk Nylon
0.0	0.0	0.0
500	24.2	21.0
1000	41.0	32.5
1500	41.4	38.1
2000	48.0	44.6
2500	53.7	50.0
3000	59.5	55.0
3500	65.0	60.0
4000	79.1	64.5
5000	89.0	69.9
6000	100.0	95.1
7300	—	100.0

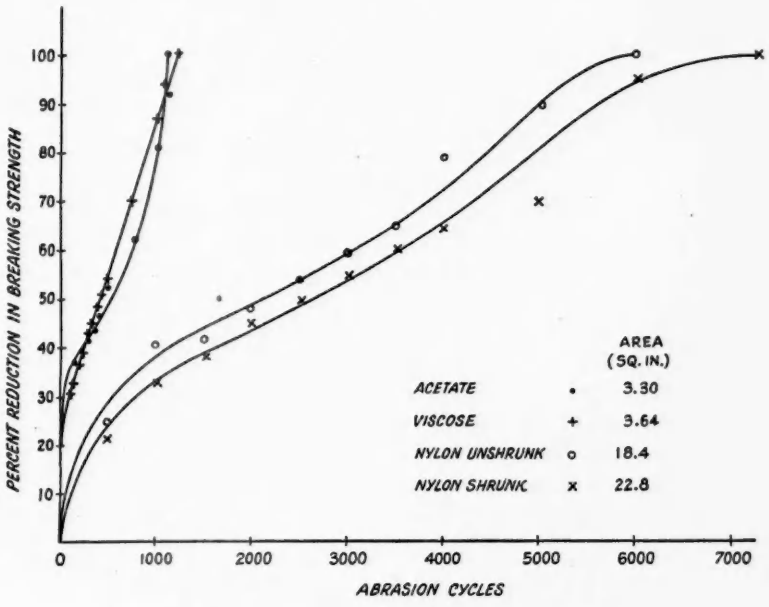

FIG. 3. *Comparison of abrasion rate curves.*

clearly defined Hooke's Law range (stress linear with strain), and hence the conventional methods of determining modulus of elasticity are not applicable. However, a ratio of load to deflection expressed as a ratio of the mean ordinate of a load-elongation curve to the ultimate abscissa (slope to the mean) is essentially a representation of an average modulus. (See Figure 1.)

Figure 1 represents a load-elongation curve for which the slope to the mean is to be determined. The area under the curve may be expressed as:

$$\int_0^x y dx$$

The mean ordinate may then be expressed as:

$$\frac{\int_0^x y dx}{x} = \bar{y}$$

If this mean ordinate is now shifted along the elongation axis to x, the slope to the point $(x, \bar{y})$ is the slope to the mean.

Similar ratios to indicate "stiffness" and "toughness" are suggested by Smith [4]. Inasmuch as a large deflection for a given load is desirable, the ratio of deflection to load will be used and termed "energy coefficient." The higher the value, the greater the energy absorption capacity of the material.

The total deflection at any point on a load-elongation curve must be the sum of the immediate elastic, the secondary creep, and the primary creep components. The secondary creep component may be eliminated by repeated loadings. After subjecting the specimen to a sufficient number of cycles to remove this component, the final path of the load-elongation curve is modified as a result of its subtraction.

Upon the complete removal of secondary creep at a given load, subsequent load-elongation curves will be alike in shape and displacement—i.e., they will superpose upon repeated loadings and unloadings. When such a condition prevails, the specimen is said to be "mechanically conditioned" [5], all secondary creep now being absent.

If a hypothetical specimen, which has not been mechanically conditioned, manifests no secondary creep, the load-elongation curve for the original cycle and the conditioned cycle will be identical. In this case, a low modulus of elasticity manifested by the initial loading cycle would depict the average energy absorption properties under repeated as well as single stress application and removal; and the ratio of deflection to load previously described would indicate its desirability. Thus, high energy absorption capacity may be expected under repeated stress for a material manifesting a low modulus, no secondary creep, a large immediate elastic deflection, and high magnitude and rate of primary creep. For this special case, the original load-elongation curve may be utilized to predict this energy absorption capacity.

If, however, secondary creep is present, the effect of removal of this component by mechanical conditioning is to shift the hysteresis loop along the deformation axis and to increase the slope to the mean. (See Figure 2.)

Figure 2 is a typical repeated load-elongation diagram for acetate rayon, the conditioning load being in this case 90 percent of the ultimate load. The mechanical conditioning was complete in five cycles, as is indicated by the reproducibility at that cycle.

The additional length of the specimen resulting from the removal of secondary creep is indicated as x_3 and must be added to the original reference gage length when calculating the percent elongation at the conditioned cycle.

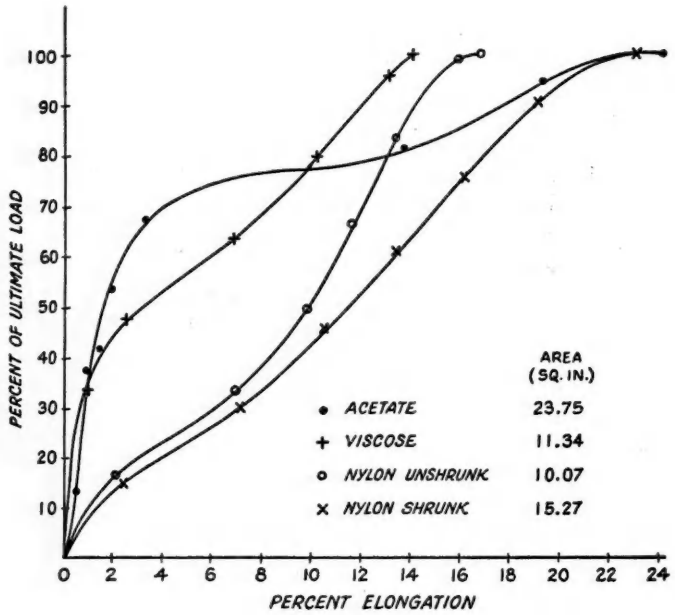

FIG. 4. *Load-elongation curves. (Materials not mechanically conditioned.)*

The path of the loading curve x_5y_5 has been modified as a result of the subtraction of the secondary creep component from the original loading curve, resulting in a higher slope to the mean and a corresponding decrease in deflection-load ratio.

Since the modified loading curve governs the energy absorption characteristics of materials subject to repeated stress, the magnitude of secondary creep is an important consideration.

To summarize, with the foregoing discussion in mind, the properties desirable in materials subjected to repeated stress application are:

1. Low modulus of elasticity.
2. Large immediate elastic deflection.
3. High ratio of primary to secondary creep.
4. High magnitude of primary creep.
5. High rate of primary creep.

In order to investigate the relationship between the factors summarized above and the resistance to abrasion, some satisfactory means of laboratory abrasion and a proper evaluation of the effects upon textiles must be established. The Taber Abraser was selected as the laboratory means of creating destruction by abrasive action. This selection was made because of the simple operation of the instrument—the fact that it abrades multidirectionally to the specimen as a whole, but essentially unidirectionally to any given point on the specimen; and because the abradant, while not absolutely constant, may be reasonably controlled, and, essentially, nothing other than plane abrasion takes place upon the specimen.

It was recognized early in this study that there exist two essentially different classes of factors which govern the abrasion resistance of textile structures: the inherent abrasion resistance of the material substantively, and the geometry of the composite structure, which may be characterized as the "form factor."

The study of "form factors" for various yarn and fabric structures has been only briefly prosecuted, and this phase of the abrasion problem will not be discussed at this time. In order to eliminate the effect of form on the samples investigated in this work, filamentous yarns, with a minimum of twist, were employed. A special technique for subjecting the specimens to the action of the Taber machine was developed, whereby the yarns were wound parallel on panels and abraded serigraph fashion.

The evaluation of the effect of machine abrasion has been discussed by many investigators. Ball [3]

TABLE II. DATA FROM TYPICAL LOAD-ELONGATION CURVES (FIGURE 4)
Percent of Ultimate Load vs. Percent Elongation
(Material Not Mechanically Conditioned. Original Gage Length 15 Inches.)

	Acetate			Viscose			Unshrunk Nylon			Shrunk Nylon		
Load (Grams)	% of Ult. load	Elong. (ins.)	% Elong.	% of Ult. load	Elong. (ins.)	% Elong.	% of Ult. load	Elong. (ins.)	% Elong.	% of Ult. load	Elong. (ins.)	% Elong.
25	13.5	0.07	0.467									
50	37.0	0.14	0.934	15.9	0.05	0.333	16.6	0.32	2.14	15.1	0.35	2.33
75	40.5	0.20	1.33									
100	54.0	0.28	1.87	31.8	0.13	0.868	33.2	1.04	6.91	30.2	1.05	7.00
125	67.5	0.49	3.26									
150	81.0	2.08	13.9	47.7	0.38	2.53	49.8	1.47	9.80	45.3	1.57	10.5
175	94.5	2.95	19.7									
185	100.0	3.62	24.2									
200				63.6	1.03	6.87	66.4	1.74	11.6	60.4	2.01	13.4
250				79.5	1.53	10.2	83.0	2.00	13.4	75.5	2.42	16.2
300				95.4	1.96	13.1	99.6	2.38	15.9	90.6	2.88	19.2
302							100.0	2.52	16.8			
315				100.0	2.10	14.0						
330										100.0	3.46	23.1

indicates that eight measurable changes are produced by abrasion:

1. Tensile strength.
2. Thickness.
3. Weight.
4. Surface luster.
5. Air permeability.
6. Color.
7. Character of abraded material.
8. Appearance of surface.

Of these, only four indicate possibilities of dependable quantitative results for the entire structure—namely, strength, thickness, weight, and air permeability.

Comparison of weight loss and strength loss plotted against cycles has been investigated [6]. Thus rate curves for both criteria of damage are obtained. Loss in weight alone has been proposed by several authors [7, 8]; but from preliminary investigation in this study it is evident that weight changes are likely to occur because of deposition of debris upon the sample during the process of abrading even if vacuum is employed for its removal. For such material structures as yarns, the differences would be of such an order of magnitude as to preclude any degree of precision and reproducibility of results. Likewise, thickness, which may be used very satisfactorily as a criterion in studying such structures as carpets [9] and pile fabrics, is not a dependable criterion for thin structural units because of the limitations in measuring small differences;

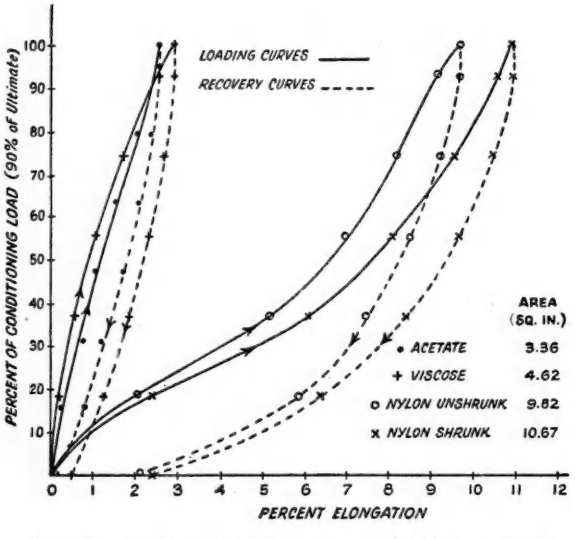

FIG. 5. *Load-elongation curves. (Materials at conditioned cycle.)*

moreover, as wear progresses, apparent thickness frequently increases because of surface distortion.

Air permeability as a measure of abrasion resistance [10] is also unreliable because debris deposited in the interstices of the specimen reduces the permeability as the test proceeds.

While strength is not all that could be desired as a criterion for evaluation of damage, it appears to offer the least objectionable features. It should be pointed out, however, that it is used strictly as a measure of the extent of damage from abrasion, and should not be taken to reflect values of durability from the standpoint of strength per se. The predominant method for the determination of extent of damage as revealed in the literature is to select an end point based either upon a given number of machine cycles [11, 12, and 13] or the formation of a hole [10, 14, 15], and evaluate the result of abrasion at such an end point. The selection of an end point is undesirable in that it precludes a study of the rate at which the sample is proceeding to destruction, coupled with the fact that it is usually impossible to define and reproduce the end point quantitatively.

Percent loss in unabraded ultimate strength versus abrasion cycles has been selected to depict both the "durability," which connotes time to reach a given degree of destruction, expressed in abrasion cycles, and "rate of destruction," which connotes the path of the percent-loss-versus-cycles curve. The use of percent-loss-in-strength as an ordinate permits comparison of materials of unlike strengths. The plot of percent-loss-in-strength versus cycles may be interpreted as a rate-of-destruction curve or, conversely, as depicting the rate and extent of resistance to destruction. If, then, a mean ordinate is calculated and the slope to this mean is determined, as in the case of the load-elongation curve previously discussed, the ratio of percent loss in strength to cycles will represent a rate of mean failure. Inasmuch as the mean ordinate is obtained by dividing area by abscissa, which represents a selected number of cycles to destruction, the durability as well as the rate of destruction is reflected by the slope to the mean. Since a large number of abrasion cycles for a given extent of failure is desirable, the ratio of cycles to percent-loss-in-strength will be used and termed "durability coefficient"; the higher the value, the greater the resistance to destruction of the material.

It has been stated earlier in this paper that the effect of frictional forces on a textile material should be proportional to the work done on the test speci-

men. Conversely, the resistance of the material to destruction should be proportional to the energy absorption capacity of the material.

If, then, the resistance of a material to destruction is proportional to the energy absorption capacity of that material, it would be expected that a proportionality exists between energy coefficients and durability coefficients of various materials. Acetate, viscose, and nylon yarns of specifications indicated below were abraded[1] on the Taber Abraser to complete destruction (100 percent loss in strength) and rate of destruction curves were plotted (Figure 3):

Acetate (bright)	150 den., 40 fil., 3 t.p.i.
Viscose (bright)	150 den., 40 fil., 3 t.p.i.
Nylon (dull) (unshrunk)	60 den., 20 fil., 1 t.p.i.
Nylon (dull) (shrunk in steam at 250°F, 30 min.)	60 den., 20 fil., 1 t.p.i.

Each point on the curves represents five serigraph panels of yarn, each of which yielded two specimens for determination of breaking strength. Thus, an average of ten breaks is represented by each percent-loss-in-strength value plotted.

Mechanically conditioned load-elongation curves were plotted for each of the four yarns.

Figure 4 depicts the load-elongation characteristics of the four yarns before mechanical conditioning, adjusted to a unit strength basis by plotting percent of ultimate breaking load in each case versus percent elongation.

Figure 5 is a plot of the loading and unloading characteristics in terms of percent strength versus percent elongation after mechanical conditioning at a load equal to 90 percent of the ultimate breaking strengths, respectively, of the four yarns. In this graph, as in Figure 4, the strength values have been adjusted to a unit basis to permit comparison of yarns of unlike strengths on an equal basis.

It will be observed that the shapes of the rate of destruction curves are similar to those of the load-elongation curves, an interesting fact in light of the results of this investigation.

Calculation of the energy coefficient *"E"* from mechanically conditioned load-elongation diagrams gave the data in Table IV.

The data in Table IV have been selected from typical load-elongation curves from a number of repeat tests.

[1] The author expresses grateful appreciation of the painstaking efforts of Melissa W. Landing in the laboratory testing procedure and the assembling of data.

TABLE III. Data from Typical Load-Elongation Curves (Figure 5)
Percent of Conditioning Load vs. Percent Elongation
(Material Mechanically Conditioned at 90% of Ultimate Load)

Load (Grams)	Acetate				Viscose				Unshrunk Nylon				Shrunk Nylon			
	% of Cond. Load	Gage at Cond. Cycle	% Elong.	% Recov.	% of Cond. Load	Gage at Cond. Cycle	% Elong.	% Recov.	% of Cond. Load	Gage at Cond. Cycle	% Elong.	% Recov.	% of Cond. Load	Gage at Cond. Cycle	% Elong.	% Recov.
0.0	0.0	17.8″	0.0	0.17	0.0	16.5″	0.0	0.55	0.0	15.8″	0.0	2.16	0.0	16.0″	0.0	2.38
25	15.8		0.28	0.84	18.5		0.24	1.27	18.5		2.09	5.88	18.5		2.38	6.45
50	31.6		0.73	1.24												
75	47.4		1.07	1.74												
100	63.2		1.52	2.08	37.0		0.61	1.88	37.0		5.19	7.48	37.0		6.07	8.40
125	79.0		2.02	2.36												
150	94.8		2.47	2.47	55.5		1.03	2.30	55.5		6.98	8.49	55.5		8.07	9.64
158	100.0		2.53	2.53												
200					74.0		1.76	2.67	74.0		8.18	9.19	74.0		9.52	10.4
250					92.5		2.55	2.91	92.5		9.19	9.70	92.5		10.6	10.9
270					100.0		2.91	2.91	100.0		9.70	9.70	100.0		10.9	10.9

TABLE IV. DATA FROM LOAD-ELONGATION CURVES (FIGURE 2)

Yarn	Areas (sq. in.)	% Ult. strength × % Elong. (20 × 2)*	% Elong. (Abscissa)	% Ult. strength (Mean ordinate)	Coeff. E $\left(\frac{\%\text{ Elong.}}{\%\text{ Ult. strength}}\right)$
Nylon shrunk	10.67	426.8	10.90	39.1	0.280
Nylon unshrunk	9.82	392.8	9.70	40.4	0.240
Acetate	3.36	164.4	2.54	52.9	0.0481
Viscose	4.62	184.8	2.94	63.0	0.0467

* Scale factors.

It is evident that the energy absorption capacity of shrunk nylon is highest, followed by that of unshrunk nylon, acetate, and viscose, in that order.

Calculation of the durability coefficients *"D"* from the abrasion rate curves yielded the data in Table V.

From Table V, it is apparent that, as in the case of energy absorption capacity, the durability coefficient for shrunk nylon is the greatest, followed by that of unshrunk nylon, acetate, and viscose, in that order. A perfect rank correlation of energy coefficient E with durability coefficient D exists for the four yarns.

Figure 6 is a plot of energy coefficients versus durability coefficients for the four yarns studied. The points lie well along a straight line through the origin. Thus, it is evident that a linear relationship exists between energy coefficients and durability coefficients, which permits comparisons on a quantitative basis.

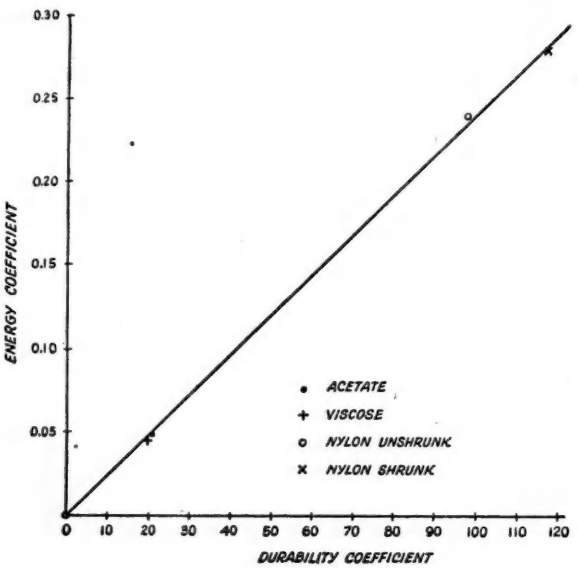

FIG. 6. *Correlation of energy coefficients and durability coefficients.*

Abrasion resistance of materials can, therefore, be predicted by the use of load-elongation diagrams of mechanically conditioned specimens.

The quantitative method for evaluation of resistance to abrasion as described herein involves the rate concept. It is justifiably claimed that an end point alone expressed as the number of cycles required to cause complete destruction is not a satisfactory criterion of resistance to abrasion. The rate at which the sample proceeds to destruction must also be considered.

Durability, which is expressed in cycles required to cause a given degree of damage, essentially represents time to destroy, while rate of destruction measures the changing condition of the specimen as it proceeds to destruction resulting from abrasion.

The slope to the mean obtained from abrasion rate curves reflects both durability and rate and is essentially an index of destruction. The ratio of cycles to percent loss in strength is an index of resistance to destruction, or durability coefficient.

The rate curve method of evaluating the effect of abrasion by laboratory instruments is involved and time-consuming, and, furthermore, evaluates the resultant destruction rather than the basic cause of failure. Intelligent interpretation of load-elongation curves of mechanically conditioned specimens yields fundamental information and is less time-consuming.

It should be pointed out that in this study as much "form effect" was eliminated as possible by a selection of yarns with a minimum of twist. However, some form effect prevails in the data presented. Further investigations of form effect are in progress.

The factors which govern the elastic behavior of textile fibers are also applicable to plastics, rubber, etc., in various geometric forms. The abrasion resistance properties of such materials may now be investigated quantitatively from load-elongation curves using the abrasion instruments for confirmation; and these may also be used to study the effects of geomet-

TABLE V. Data from Abrasion Curves (Figure 3)

Yarn	Areas (sq. in.)	% Loss × Cycles (20 × 1,000)*	Cycles (Abscissa)	% Loss (Mean ordinate)	Coeff. D $\left(\frac{\text{Cycles}}{\% \text{ Loss}}\right)$
Nylon shrunk	22.8	456,000	7,300	62.5	116.7
Nylon unshrunk	18.4	368,000	6,000	61.5	97.5
Acetate	3.30	66,000	1,150	57.5	20.0
Viscose	3.64	72,800	1,200	60.5	19.8

* Scale factors.

ric form factors which may not be reflected in load-elongation curve data.

The effect of geometric form factors will undoubtedly be more pronounced in structures such as woven, knitted, or braided fabrics than in sheets, films, and extruded items, since in the latter types geometric variations will undoubtedly be reflected in the load-elongation data.

The face and the back of a certain woven fabric resist abrasion quite differently, because of geometric form factors. From the load-elongation curves it is impossible to differentiate between the two surface characteristics in this case. Thus, the study of form factors will require the use of both the load-elongation curves and the abrasion rate curves for this work, at least until such time as satisfactory and sufficient form factors are determined.

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Wear Resistance of Apparel Textiles: A Literature Survey

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THE following literature survey was prepared for use in conjunction with an investigation* upon wear and abrasion resistance of apparel textiles.

The scope of the survey is intended to cover abstracts and articles in available periodicals which deal with textile and related fields and to assemble the observations and opinions of various individuals and groups. The material selected is confined to the subjects of wear, resistance to wear, and factors affecting wear, emphasis being placed upon wear by abrasion. Also included are short descriptions of machines and methods for measuring certain wear factors as found in service or imitated in the laboratory. Several of the articles are reports on conferences.

The following publications were covered in this survey: (1) *American Dyestuff Reporter*, (2) *American Society for Testing Materials, Committee D-13 on Textile Materials*, (3) *Chemical Abstracts*, (4) *Journal of Research, National Bureau of Standards*, (5) *Journal of the Textile Institute*, (6) *Rayon Textile Monthly*, (7) *Textile Colorist*, (8) *Textile Manufacturer*, (9) TEXTILE RESEARCH, and (10) *Textile World*.

A—Methods, Techniques, Observations, and Evaluations

American Dyestuff Reporter

1. 1938, **27**, 113–5. From **"Textile Testing, Part I—Physical Testing.** Chapter 7—Fabric Testing (cont.); Serviceability, Wear, Abrasion." J. H. Skinkle (Lowell Textile Institute). "Serviceability"—length of life of fabric up to its end of usefulness, which is when one necessary property becomes deficient. "Wear"—amount of deterioration due to breaking, cutting, or removal of fibers. Factors causing wear:

1. Direct force on fabric—never in normal wear; only under abnormal stress.
2. Impact effects—important only in floor coverings.
3. Flexing, or friction of fiber on fiber and yarn on yarn due to bending of fabric—ordinarily minor because wear is slow except in sized or weighted fabrics.
4. Abrasion: (*a*) friction of cloth on cloth locally, as at armpit; (*b*) friction on external objects—most important; and (*c*) friction on dust or grit internally cuts the fibers—depends on usage and cleaning practices.

Main factors in abrasion (at constant temperature and humidity):

1. Character of motion: (*a*) rotary and (*b*) reciprocating (separate warp and filling effects).
2. Nature of abradant: (*a*) the sample itself, (*b*) standard cloth, usually canvas—abradant wears, also; (*c*) steel surface—variable; and (*d*) carborundum, emery-covered fabric—rapid results.
3. Pressure of abradant on sample.
4. Tension on sample.
5. Removal of lint: (*a*) vacuum, (*b*) centrifugal, and (*c*) rock and brush abradant.
6. Determination of end point or amount of abrasion: (*a*) number of strokes to wear hole—a bit uncertain; (*b*) loss in strength at given number of rubs—repeated tests; (*c*) loss in thickness—not good except in heavy pile; (*d*) loss in weight—not good because lint, debris present; and (*e*) change in porosity, compressibility, heat and water insulation, etc., in special cases.

2. 1940, **29**, 637–41. **Determination of wearing qualities by airflow measurements.** E. J. Saxl. Suggests use of apparatus which will measure permeability of air through a fabric as a means of observing rate of abrasion or wear in the testing of the

* Portion of a research program on the wear resistance of apparel textiles sponsored by the National Research Council and conducted by the Textile Division of the Massachusetts Institute of Technology, Cambridge, Mass., and the Fabric Research Laboratories, Inc., Boston, Mass.

fabric progressively. Ordinary tensile strength measurements are usually carried to break, at which event no more wear can be studied on that specimen. Repetition of test on another supposedly equivalent sample must be carried out to bring the second piece to beyond the number of cycles at which the first piece was tested for tensile strength. This is cumbersome, takes much time, and allows too many opportunities for human and mechanical error and a large supply of sample material must be available. Moreover, tensile strength is only one factor in wear determination.

Tentative abrasion specifications (A.S.T.M.) are: (1) 96 double-rubs per minute; (2) 5,760 double-rubs per hour; (3) 3.5-pound load on abrading surface; (4) 6-pound tensile stress upon abraded sample; and (5) No. 6 Army Canvas Duck as abrasive material.

Samples are tested in permeability measuring device developed by Saxl Instrument Co. (Providence, R. I.), which has a variable air flow and flow-meter to read directly the quantity of air passing through a measured area of fabric in a given unit of time. By comparison of rate of air flow through a given sample at different cycles of wear it is possible to correlate to some extent the permeability (sometimes called porosity) of that sample with the abrasive wear it has received. Example:

Air flow without sample—10 cubic feet per minute.
Air flow with sample — 2 cubic feet per minute.
Two-tenths, or 1/5, as much air passes.
Therefore permeability is 20%.

In practice this means of analysis gives excellent curves which show that where straight line begins is the formation of a hole; i.e., 100% permeable. By plotting permeability percent against cycles of rubbing, it is not difficult to obtain a smooth curve on which most points do not deviate to any great extent. By observing the slope of the curve, it is practical to connect this value with the initial rate of wear of the textile material, noting that the steeper the slope, the less does the fabric resist (abrasive) wear. Then, too, by observing where the linear relationship begins to change into an exponential (approach to 100%) it is possible to tell when a hole starts without recourse to human observation, which is notoriously uncertain. This method is claimed to have precision and to be economical of time and money.

3. 1941, **30**, 491. **Serviceability comparisons.** H. Fletcher, M. C. Boyer, and M. C. Floersch. Tests were made to compare serviceability of wool, rayon, and wool-rayon mixtures. These included breaking strength, elongation, abrasion, shrinkage, crease-resistance, and dry-cleaning. Relative wearing quality was obtained by comparing breaking strength of original fabrics with that of samples which were abraded by a Massachusetts Institute of Technology model abrasion tester, using crocus cloth as an abradant for 500 rubs. Mixtures of wool and rayon yarns had greater abrasion resistance than either wool or rayon fabric alone. Shrinkage was also much greater for the mixture.

Rayon Textile Monthly

4. 1942, **23**, 85 (June). **Abrasion resistance tests by United States Testing Company** (hosiery abrasion tester). United States Testing Company has setup to try perspiration effects. They also found that by rearranging and reinforcing areas via twist changes, ply variations, and special platings without changing the composite yarn size or type of fiber the abrasion resistance may be materially increased.

5. 1944, **25**, 72 (January). **Physical properties of 26 work garment fabrics.** M. B. Hays of Bureau of Home Economics, U. S. Department of Agriculture. Tests were made on gabardine, osnaburg, poplin, jean, herringbone twill, whipcord, suiting, pincheck, and sportswear denim. Abrasion wear tests were performed with the Taber machine and the Wyzenbeek machine: the former rubs in a circular path on continuously changing direction, whereas the latter rubs in a back-and-forth motion either warp-wise or filling-wise. Degree of loss in tensile strength was measured by the grab, half-grab, and strip methods. On comparing number of cycles to produce a hole with weight per yard, trend was that heavier fabrics showed more resistance to abrasion. Both methods of test show that gabardine, herringbone twill, and whipcords are most resistant to abrasion and also have highest breaking strength, both in warp and in filling. Serviceability tests will show how they correlate.

American Society for Testing Materials—Committee D-13 on Textile Materials

6. *1941 Annual*, pp. 349–50 (October). **Correlation between laboratory abrasion tests and the service life of men's and women's outerwear.** Arthur Russman of Howard Manufacturing Corp. (October,

1940). Study to develop laboratory procedure and technique in order to predict service life of garment material. There was extensive investigation of commonly used outer apparel of woolens, worsteds, serges, fancies, gabardines, tropicals, cashmeres, tweeds, homespuns, cheviots, coverts, all types of woven and knitted top, and of overcoating, such as velours, tweeds, bouclés, and pile fabrics. Rayon body and sleeve linings were also studied.

"Master" samples of discarded and worn garments were kept for reference. Characteristic wear areas, as at cuffs, pockets, under-arms, backs, and edges of garments, were studied and eventually duplicated quite closely by laboratory methods.

Workers put most of their reliance on the use of a Wyzenbeek Precision Wear Tester Meter, which was modified to give 120 oscillations per minute, removing the suction system for lint in order to remove it at periodic stops for observation (5- or 10-minute intervals). Size of sample, pressure, and tension on sample and abradant were standardized, and warp-wise and filling-wise runs were made at various selected areas (folded and flattened "S" strips were made to represent edges, as at cuffs or pockets). Visual inspection was used to determine "end-point" at which a set of yarns were at or near rupture. By past experience (as judged against "master" samples) the investigators arrived at a degree of wear for each type of material on a designated piece of apparel which was accepted as "a season's wear" for that goods. Then they attempted a correlation with rubs of the test apparatus to compare number of single rubs to rupture (end-point) with a "one month's wear factor" for that particular kind of goods in order to predict how many months a suit should last with "normal" use. They set arbitrary values for "poor," "fair," and "good," which prove satisfactory for the purpose.

7. *1941 Annual*, pp. 359–65 (October). **Relative merit of three rayon taffetas in consumer service.** Alexis Sommaripa, Fabric Development, E. I. Du Pont de Nemours and Co. An illustration of consumer wear tests in use (1) to compare life span of fabrics in actual service, (2) to ascertain degree of resistance in wear to specific types of deteriorations, and (3) to correlate laboratory tests with results secured in service.

This paper presents history of three taffeta-type fabrics and is limited to deterioration due to distortions. Other serviceability tests are being accumulated: they mention resistivity of different fabrics to other sources of deteriorations—such as fuzzing up of filaments, holes, holes near seams, etc. As factors which increase resistivity to these various deteriorations are isolated, new fabrics are constructed and tested by consumer use to find out possibilities for improvement.

A great deal of detailed information is given in the article as to number of wearers, how samples varied in construction and wearability under fairly well controlled conditions of inspection, laundering (by wearer), duration of wear, and periodic degree of wear (photographs). Statistical analyses of significance of results were made. Graphs and charts show rate of deterioration due to distortions for each type of fabric (graph), and tables were charted showing all the data of construction, hours, number of wearers, washes, inspection results, repairs, coefficients of variation (%), and many other statistics as well as estimations. Costs per year were arrived at for each fabric. This has consumer interest.

Results of number of washings and hours of wear were compared, and distortion was correlated with slippage resistance.

By these tests superiority of fabrics is clearly shown in dollars and cents on an annual basis. Relative importance of type of wear may also be studied.

Chemical Abstracts

8. 1934, **28**, 7027[6]. **Wool fabrics.** Reference is made to effect of acids and alkalies on wet and dry strength of wool. After such treatment wet strength does not correlate with dry strength.

9. 1938, **32**, 5220[4]. **Wearing quality of fabrics** determined by physical characteristics (*American Dyestuff Reporter* **27**, 257–60, 284, 1938). A fabric with warp and filling threads equally balanced usually gives greater wear than a poorly balanced one.

10. 1938, **32**, 5642[6]. **Tear resistance.** A German patent 659,116 gives a method for making wool fabrics more tear-resistant by treating them with solution of formaldehyde with highly sulfonated Turkey-Red oil and an acidity of 5 pH.

11. 1940, **34**, 5286[8]. **Durability of cotton fabrics.** Methods for determination of the durability of cotton fabrics. Smith apparatus using corrugated bronze rollers produced type of wear on fabric which differed from natural conditions of wear. Substituted wood rolls with test-fabric coverings. Stretch resistance recorded as "fatigue." Folding tests for resistance were measured by apparatus of Schopper. Samples folded along warp and along filling were

compared: found more resistant in direction of filling than of warp. They folded 154,278 times in 18 hours. With the same number of foldings the reduction in strength is less along the filling than along the warp. As regards stretching, the numbers are reversed. The decrease in elongation is less in the direction of the warp. Laundering causes loss of strength up to 16.5% and even pure water alone causes 17% damage if fabric is laundered 30 times (warp). The most important wear factors are rubbing, continuous folding, and bending and stretching. Chemical factors are light and moisture. Clothing wear is divided into (1) friction 50%, (2) folding 26%, (3) stretching 22%, while another test shows chemical action (oxidation) to account for 8%. Coat materials are more affected by oxidation and hydrolysis and less by friction and folding.

12. 1940, **34**, 5288[1]. **Increasing wear resistance of textiles.** Incorporation of various amounts of fats helps.

13. 1940, **34**, 6085[6]. **Method of determining durability of cotton.** First make chemical tests: hypochlorite and then artificial perspiration. Then give mechanical treatment to simulate wear—such as bending, stretching, etc.

14. 1940, **34**, 8292[9]. **Effect of finishes on wearing qualities** (*Melliand Textilber.* 1938, **20**, 565–9). Removing scale of wool or cuticle of cotton lowers wear resistance. Hardening renders some fibers less resistant to bending, stretching, etc. Ideal would be center fiber of resilient plastic with flexible coating resistant to chemical and mechanical attack.

15. 1940, **34**, 1494[5]. **Increased wearability.** Fats, oils, and glycerol increase wearability of fabrics. Lubrication may be done by apparatus.

16. 1940, **34**, 1180[6]. **Theory of viscometric method of determining wear resistance of cellulose materials.** Fabric was washed repeatedly in boiling weak alkali solution. A piece was dissolved in copper-ammonium sulfate and the viscosity measured, using a capillary viscometer. Washings decreased viscosity (η) in almost linear relation.

17. 1941, **35**, 4973[3]. **Wear resistance** increased by adding wax, rubber dispersions, and soaps.

18. 1943, **37**, 4577[5]. **Improvement in serviceability of wool uniform cloth** (German). Washing methods are compared. Neutral or slightly acid solutions cause little damage and shorter drying periods with less danger of bacterial decomposition. Wearability is not significantly affected by the type of washing; slightly acid washing apparently is more advantageous. In alkali washing and fulling, excessive concentrations and temperatures cause damage which lowers the wearability appreciably. Dyeing has greater effect than washing and fulling. Greater color depth gives improved wearability. Chrome dyes are better than vat dyes.

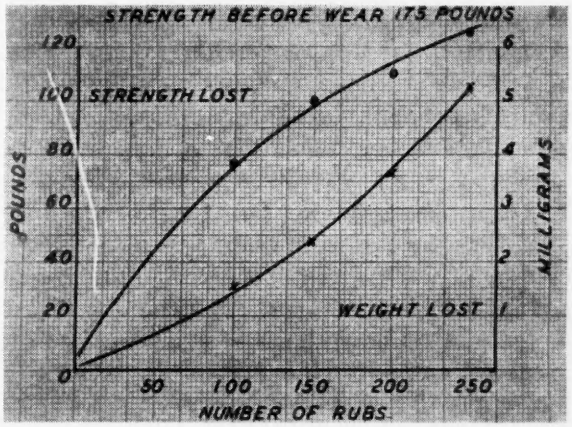

FIG. 1. *Relation between loss of strength and loss of weight.*

Journal of Research, National Bureau of Standards

19. 1942, **29**, 333–79 (November). **Wear on carpets.** H. F. Schieffer and R. S. Cleveland. A continuation of articles reported in *Textile Manufacturer* **60**, 182 (1934) from "Research Paper 640" of the *Journal of Research* **12**, 155. The 1942 article says that tests on 24 carpets by different laboratories using two types of tester (National Bureau of Standards Carpet Tester and Shawmut) were correlated with 3-year service tests. There was a deviation of less than 10 percent in nine out of ten cases, which was due to non-uniformity of test conditions. Photographs and other data are given.

Journal of the Textile Institute

20. 1931, **22**, T56. **Permeability of fabrics to air.** M. C. Marsh. Found milled fabrics to be less permeable to air almost in proportion to milling (felting, etc.).

21. 1931, **22**, T64–76. **Experiments in fabric wear testing.** H. Crawshaw, W. E. Morton, and K. C. Brown. Wear tester uses carborundum abradant, gives measured number of rubs, and compares strength lost with weight lost at each rub number level. Weight loss is all over, whereas strength loss is directional, using cotton fabric along warp surface, then along filling surface. (See Figure 1.) There were, however, some inconsistencies in the abradants used. Different areas of the same abra-

dant varied in wearing activity. Need some means of standardizing abradant. Other abrasives were used besides carborundum but none gave equal results over more than 10 hours' usage, which is unsatisfactory as a standard.

22. 1931, **22**, T531. **Fabric testing methods.** The resistance to wear by rubbing increases with increasing closeness of weave and with increase of yarn twist, whether or not the warp or filling yarns are under tension during the rubbing. It depends on the state of the cloth whether the result is higher in the warp or in the filling specimens. With either sort of specimen the result depends on the structure of the cloth as a whole. Resistance to laundry wear depends on the closeness of weave and the yarn twist. Wear always shows first as breakage of warp threads near the selvedges. The properties and the closeness of the setting of the warp yarns appear to be more important than those of the filling. The number of washes required to cause wear appears to be related to the rate of loss of weight, while the loss of weight which takes place before wear appears to be related to the closeness of setting of the warp yarns.

23. 1934, **25**, T133–40. **Abrasion testing of knitted textiles.** W. Davis. Materials used were a reciprocating abradant and an inflated ball with controlled pressure inflation under the piece of fabric tested. Temperature change in progress of abrasion is recorded. Results depend on (1) material of fabric, (2) pressure inside ball, and (3) direction of travel of abradant. Reciprocal of number of rubs and pressure is nearly linear. Cotton knitted fabric rubbing on wool is less harsh than wool on wool (which by rasping action wears a hole quickly). Also a rapid temperature rise is noted in rubbing wool on wool.

24. 1934, **25**, T198. **Perspiration.** Normal perspiration averages 1 to 1½% total solids in water solution in this approximate proportion: sodium chloride, 50%; other salts such as phosphates, sulfates, and chlorides of magnesium, calcium, and potassium, 10%; nitrogenous matter (urea, etc.), 30%; organic acids (lactic, and perhaps some acetic), 10%. This is usually weakly acid, but on standing becomes strongly alkaline in reaction. There are two forms of perspiration: (1) "sebum," a lubricant of acid nature, and (2) the water solution of normally alkaline sweat, which functions to regulate body temperature. Effect of perspiration: (*a*) promotes bacterial growth and (*b*) causes deleterious effects from salts contained. Wool is felted by alkaline sweat. Over-chlorinated garments are susceptible to alkaline hydrolysis, causing them to break down into holes. Sodium chloride and salts tend to weaken cotton and silk.

25. 1935, **26**, T71. **Temperature of abrasion on knitted fabrics.** Continuation of work of W. Davis in 1934 (see reference 23). He found differing fabrics and weaves give varying temperature rises in abrading.

26. 1937, **28**, 173–266. **Serviceability of fabrics for clothing.** Annual conference of the Textile Institute (in England), June 9–11, 1937. F. T. Pierce's article (see reference 45, page 185). T. C. Petrie tells of effects of different kinds of perspiration in different racial groups. Points out areas of greatest wear at collars, folds, ribbing, corners, binding, etc. J. H. Lester claims cloth-on-cloth rubbing is not entirely satisfactory as a test of wear (Herzog-Geiger Method). Different abradants give different results, so one may use certain kinds for certain qualities being investigated. Amsler type of test (reference 82, page 189) minimizes surface friction and emphasizes internal fiber wear quality. Other types tease apart fibers and draw out some. Subject of wear testing is tangled mass of information; need to find relative importance of characteristics of each fabric for whatever purpose it is to be used. Ring-wear tests do not always indicate relative wearability in actual service in same degree as test. J. C. Mann found that when he sent two samples of fabric to five different testing laboratories to be abrasion-tested in presumably the same way, some testers found one sample to be better than the other, while other testers found the reverse to be true. Still others found variations in the results according to how the samples were held while tested and other variations. No wear tests were possible in actual use, so who was right is still unknown. Other factors than abrasion were likely to have influenced results.

W. Pritchard finds testing of fabrics in laboratory the only practical procedure; no time to service-test all shipments; can tell from the tests and past experience which is good fabric.

27. 1939, **30**, A260. **Cotton fabrics: wear testing.** Suggests chemical treatment prior to mechanical testng. Treatment with acids, synthetic perspiration salts and acids, and other imitative treatment to simulate wear. Bending, elongation, and ironing are also suggested.

28. 1939, **30**, A411. **Yarns and fabrics: testing.** F. Kurtz in Klepzig's *Textil-Z.*, 1939, **42**, 275–8. Claims breaking load and extension tests alone do not tell whole story of wear. Elasticity and bending resistance tests by Zopprits wear tester and Schopper fabric bending resistance tester are described. Shows finishing treatments have little effect on strength of viscose rayon fabrics but are very different under repeated bending.

29. 1939, **30**, A723. **Finished textiles: resistance to wear.** O. Mecheels in *Melliand-Textilber.*, 1939, **20**, 565–9. Author shows that finishing treatments frequently give lower resistance to wear although the strength is apparently unaffected. Depositing resin finish as a film in ductile state is better than impregnating.

30. 1939, **30**, A786. **Italian fabrics: resistance to wear.** G. Cesconi has modified the planetary movement of his mushroom-shaped wear tester so that sample is subjected to abrasion more in conformity with actual wear.

31. 1939, **30**, A789. **Methods of testing textiles and clothing at Bureau of Home Economics,** U. S. Department of Agriculture. M. B. Hays in *Journal of Applied Physics*, 1939, **10**, 539–41, shows how the Bureau tests strength, stiffness, thickness, warmth, resistance to abrasion (Massachusetts Institute of Technology abrasion machine), fastness to light and washing and surface reflection of fabrics.

32. 1941, **32**, A469. **Fabrics: wear testing by air permeability.** E. J. Saxl in *American Dyestuff Reporter*, 1940, **29**, 637–41, tells of disadvantages of visual and strength tests to find damage done by abrasion; claims measuring permeability to air flow before and after abrasion is better way. Curve obtained by plotting porosity (as measured by air flow through sample) against abrasion cycles shows linear increase in porosity with cycles at beginning of tests but becomes exponential as approaches 100% porosity. Point of change in character of curve indicates that a hole is being formed in the fabric. Slope at beginning shows material wear characteristic of fabric being tested.

Textile Colorist

33. 1940, **62**, 121. **Testing porosity of fabrics.** C. H. S. Tupholme. "Porosity" defined as reciprocal of pressure difference between two sides of fabric required to produce a flow of unit volume of air per unit time through unit area of fabric. Measurement of "porosity" comprises three parts: (1) defining area of fabric to be tested; (2) accurate defining of air flow through fabric; (3) measurement of pressure drop between two sides of fabric. British Air Ministry on balloon, parachute, and aircraft fabrics requires that resistance to air flow shall be 14.4 cubic feet per square foot per minute constantly through 10 square inches of material with pressure on fabric between 0.125 pound and 0.264 pound per square foot when determined in an approved apparatus in ordinary humidity conditions. They use a tilting micromanometer. May use other textiles.

34. 1940, **62**, 122. **Efficiency in consumption.** A. Sommaripa. Results of consumer wear tests by employers of large clothing retailers, 800 people participating. Products of certain weaves which were considered good were found to be low in wear resistance and were discarded early. This apparel cost "consumer" $4.72 per year. Another weave (of higher yarn count) cost only $3.64 per year, or 23% less. In addition, it was found that item 1 needed 39 repairs per year, whereas item 2 required only 15. A covered edge seam added to item 2 doubled its life and brought annual cost down to $1.84. Consumer was misled by apparent greater weight of item 1 (coarser weave) and thought it would wear better than finer and softer weave of item 2. But lower price (initial cost) of item 1 tempted consumer to buy less efficient material. An even better grade of goods with finer weave and especially made seam required no seam repairs and cost only $2.21 per year; had greater appearance value as well as wearability. Previous experience of wearers was basis of time to discard article as "worn out." Great variety in wear periods, types of wear, laundering practices, and many other factors were leveled out by comparing two large groups of wearers of the same type of garment. They were found to average very closely in results for the two. Percentage deviation from average controls number who must participate in wear test. In one test, 200 persons completed the test on three articles, with average deviation of three articles around 60%: thus minimum number of participants should be about 145. In an item requiring fewer repairs, deviation was 43.9% and the required group was only 74 wearers. When comparing two items used by the same wearer (as in example of item 1 and item 2 above) only 23 wearers are necessary. It was found better in controlled tests to have decision of time to discard left to laboratory staff, although wearer could express an opinion: this gives greater stability in determining span of life.

Typical examples of stages of deterioration and types were selected and used as standards. Frequent examinations by the laboratory kept wearers from using articles beyond 100% deterioration. "Use tests" are valuable in measuring relative efficiency in consumption.

35. 1941, **63**, 227, 268, 311, 323, 625, 688. **U. S. Department of Commerce, National Bureau of Standards—tests for fabrics.** These specifications do not include wear tests but only physical tests and chemical tests on the fabric as received for test.

36. 1942, **64**, 128. **Army times wear and tear to measure life of uniforms.** Army Quartermaster Corps gives study of approximate life of an average soldier's uniform and replacement items in second year of service. Comparison in wearing quality of wool versus that of cotton is interesting. Complete figures are itemized. These are easily available and are therefore not given here.

37. 1943, **65**, 105. **M. R. Wainer of Office of Quartermaster Corps.** Report on work carried on at Camp Lee concerning apparel wear in combat course.

38. 1943, **65**, 138. **New fabric for mountain troops.** Trials of a new fabric which is wear-and-tear-resistant to a high degree for mountain climbing and rough service show results to be very satisfactory. Fabric is a sateen weave, 9-ounce material with a waterproofed finish.

Textile Manufacturer

39. 1932, **58**, 212. **Relative durability of textile fabrics.** A. Rosenzweig of Servitor Laboratory, Austria. Durability is not measurable by strength tests. In stretching, the time factor and elasticity are important: stretched fabrics are virtually worn. Silk is three times as stretchable as cotton, but fine cotton yarn is about 25 times as strong as silk. Durability is measured by amount of material rubbed off and not by energy expended in doing it. Producing a hole by rubbing is durability test and time consumed in doing so at constant and suitable pressure, velocity, and roughness of rubber is found to be proportional to the durability or practical life of the fabric. Static electricity and heat from rubbing affect results. Rubbed off powdered abradants also affect results. Relation between test time (T) and pressure (P) and velocity (V) is:

$$T = \frac{1}{\sqrt{P \times V}}$$

Fabrics owe their durability to four properties: (1) density (cotton, linen); (2) elasticity (wool); (3) smoothness (silk, rayon); (4) weave.

Depreciation on any of these shortens durability. Short fibers give less elasticity, low durability. Under-shrinkage, overstretching, and weighting lessen durability. Luster and smoothness are not the same. Lowering of durability of wool may be from (1) using more recovered wools, (2) weighting, as with metallic dyes, (3) insufficient shrinking or stretching, (4) too vigorous scouring, or (5) alkaline damage to the wool. Contrary to tensile strength indications, it is found that luster wools are less durable than worsteds, and worsteds less than woolens. Crepe which showed no serious defect by strength test, in a rubbing test showed durability far below standard and actually was rubbed into holes on first wearing. Egyptian cottons are more durable than linen, and linen is more durable than wool.

Conclusion: Rubbing tests show which are best for durability: rayon 0.03; silk 0.17; wool 1.0; linen 1.9; and cotton 4.3.

40. 1932, **58**, 218. **Minimum wearing strength of textile fabrics.** J. G. Williams. Fabrics in use meet with "normal stress." When worn out, there is failure of the material to resist these stresses and so the fabric fails. Therefore, the life of the fabric is expressed:

$$\text{Life} = \frac{\text{Original breakdown strength—Normal stress}}{\text{Rate of deterioration or wear}}$$

Textiles are tested to set a standard or to make comparisons. The other phase is to predict probable satisfaction of the fabric in future use. Tensile strength tests made on worn fabrics to standardize "normal stress" were labeled (1) "slightly worn," (2) "worn" (not worth repair or likely to tear in laundering), and (3) "seriously worn." Tests used were in air-dry condition using grab test with jaws 4 inches wide and 4 inches apart with 6-inch samples. General average of various fabrics was tension of 40 pounds (observed to be average human pulling strength in use or in washing). Bursting strength on a Mullen bursting tester was about 37 pounds per square inch. These "normal stresses" indicate when fabric may be considered "worn out." Wet strength is taken as about 20 pounds in the grab test. Below 20 pounds fabrics tear when wet even with careful handling.

41. 1934, **60**, 182. **Wear of carpets.** H. F. Schiefer and R. S. Cleveland. Different types of

velvet and carpet fabrics were exhaustively tested for wear at the National Bureau of Standards. Density of pile is predominant factor in wear resistance of carpet. Pile height is secondary. It was noticed that areas which were dyed different colors wore at different rates. It was also noted that longer boiling of yarns caused shorter life. This may be tied in with color of dye (boiling time, if any). Of course, stiff fiber yarn wore quicker than medium fine fibers, which stood up better in resilience to bending and withstanding slippage, such as occurs at anchors in the filling. Wear index was approximately proportional to pile density squared and pile height. Underlays increased wearability as much as 146%. Those containing jute alone matted down and were less effective. With cotton, animal hair, paper, and rubber better results were obtained. Wear index was higher for better wear resistance (a positive value for durability).

42. 1935, **61**, 230. **Experiments on fabric wear.** J. H. Lester. Results of tests show that fabrics having poor resistance to surface friction may show great resistance to internal friction and bending.

TEXTILE RESEARCH

43. 1934, **4**, 348. **Fabric wear resistance and methods of measuring it.** U. S. Institute Conference. Wear type is important: test should represent it. Linings should be tested in conjunction with (artificial) perspiration treatment. It is necessary to check back on any form of test to see if actual wear conforms to predicted wear. All tests should be done at uniform humidity, temperature, and with standard equipment if possible; abradant should be the same for each test for abrasion, etc. Time element should be the same each time, and in any event should not be so highly accelerated as to give a false picture of wear resistance in use: should rub, not cut fabric. Should study fabric and fibers and note relation of same in regard to wear. Other types of wear than abrasion should be tested, such as flex, fatigue, tearing, slipping, catching, gouging, stretching, compression, and others.

44. 1936, **7**, 37 (November). **Fibers: Testing of flexure breaking strength** (*Melliand Textilber.*, 1936, p. 120). Abrasion does not tell whole story of wear. Flexing fibers 200 times a minute on an oscillating clamp to break gives another factor of wearability; apparatus measures geometrical mean.

45. 1937, **7**, 381–4 (August). **Serviceability of fabrics in regard to wear.** Abstract by F. T. Pierce from Conference of the Textile Institute in England —June 9–11, 1937. Reprinted in *Textile Manufacturer* for June, 1937.

Abrasion is not absolute test of serviceability. Microscopic examination shows cloth rubbed against emery to suffer clean cuts unlike actual wear marks. Tensile strength as a test is not true to life although it has points of value. Heat treatment is only a rough measure of "ageing." All tests are rather loosely connected with actual service conditions. Drying, pressing, and laundering in general have effect on wear, as does shrinking or stretching. In general, imitative tests are of value only if their relative importance is carefully and analytically determined and correlated with field tests. Main value of these tests is to discover weaknesses and try to strengthen such characteristics. Function of testing is not mere imitation. In order to correlate fabric character to service requirements, it is necessary to (*a*) study the fabric through tests of staple, structure, strength, resistance to abrasion, etc., (*b*) recognize and evaluate destructive agents, and (*c*) determine to what extent each destructive action may be correlated to the known and measured characteristics of the fabric. Deterioration is difficult to measure and serviceability prediction is largely guesswork. Comparisons of nearly alike samples show up types of failure: controlled service tests should show what causes each type by simplifying the human element as much as possible and observing cause and effect.

Fabric coherency is a factor in serviceability which may be measured by tensile strength tests although actual wear has many other factors, such as abrasion, bending, and various mechanical, physical, and chemical components. The relative ability of a fabric to hold together is a criterion of its potential wearability, although the usual tests do not tell the whole story.

Useful life of a fabric may be terminated by other things than wear: length measurements, color changes, bagging, or other deterioration in fabric character may sometimes be as important as wear resistance.

Quality of apparel while being used is pertinent to its serviceability, as well as determining its endpoint of useful life. Analysis of samples should take account of variability and show up weak members. Progressive wear may alter predominant characteristics: tests by rubbing show size to be ad-

vantageous, but too much size is shown only by bending tests.

Probably the most fertile application of testing in regard to serviceability is not in foretelling duration of life, but in correcting weak features. Statistical analysis of the results of destructive tests is essential to sound interpretation.

46. 1938, **8**, 134–7 (February). **Problem which abrasion and wear tests present,** by Herbert J. Ball, chairman of Committee D-13 of American Society for Testing Materials. The first part of this address is concerned with description of eleven abrasion- and wear-test machines. The problems involved are: (1) terminology, (2) universal machine or method of abrasion, (3) requirements for satisfactory laboratory test, (4) difficulties of correlating wear rating with service tests, and (5) measure of effects of abrasion.

1. Definition of terms: (*a*) "abrasion"—"rubbing off" test or machine, and (*b*) "wear"—everyday use which involved many factors besides abrasion. Ultimate consumer wants "wear" and manufacturer requires tests to predict wearability.

2. There is not and there can be no universally practicable gadget to test every type of wear on every kind of fabric to meet all conditions found in usage of materials.

3. A satisfactory laboratory test should show which of several fabrics will stand up better under the conditions it must meet in service. First find which forms of wear are most important, then try to fit tests to available fabrics in order to compare corresponding characteristics which resist these conditions. Then pick the fabric which supplies the most favorable qualities and bolster up any apparent weaknesses. Selected procedure may or may not closely duplicate actual conditions of use.

4. The problem of correlating wear ratings with service tests involves human variables as well as material circumstances. Therefore, to get a representative valuation, many persons must participate in all conceivable environments and conditions or extended times to minimize inaccuracies of individual judgment and peculiarities of the wearer or recorder. Controlled methods and machines are more reliable in detecting and eliminating individual wear problems.

5. Measuring abrasion effects is a quantitative method for evaluating the effect of frictional forces on the textile and should be proportional to work done on the test sample. Eight measurable changes are produced by abrasion methods: (*a*) tensile strength, (*b*) thickness, (*c*) weight, (*d*) surface luster, (*e*) air permeability, (*f*) color, (*g*) character of abraded material, and (*h*) appearance of surface.

The qualities most important in serviceability in each case should be emphasized in the testing; thus if strength is most important, evaluate by tensile strength comparisons.

There are limitations, however. Effect of wear is not always proportional to work done. Fuzziness, broken fibers, abradant particles, etc., affect thickness, weight, air permeability, and other qualities in a way to render the observed readings untrustworthy in certain instances on certain fabrics.

Careful planning and selection of tests plus sound judgment in observing and interpreting results count more than numerical valuations.

47. 1942, **12**, 2–7 (September). **Flexural fatigue.** Along with breaking strength, elongation, and abrasion, much may be learned of fabric by testing its flexibility and fatigue from repeated bending. A Massachusetts Institute of Technology folding tester which bends fabric through 135 degrees with a constant stress applied, measures the number of bends which are necessary to cause excessive strain to exceed the elasticity limit of the fibers. Related tests on breaking strength and elongation show that yarn and fabric construction are influential in breakage of fibers. Percentage decrease in breaking strength and in elongation due to folding show a much larger percent decrease in fabrics made of acetate rayon, Fortisan, and silk, compared with no decrease for fabrics made from viscose rayon, nylon, and cotton. This is probably the result of structural differences in the yarns and in the fibers making up the yarns.

Textile World

48. 1934, **84**, 852 (April). **Wear and wear-testing.** U. S. Institute for Textile Research in conference in New York aired many views on the subject.

"Abrasion is most important, but there is great difference between maximum and minimum wear resistance of same type of material, showing need of a comprehensive and systematic study of wear resistance from all angles."—E. Freedman of R. H. Macy & Co.

"First step is to examine worn fabrics to see what happens in practice; then make testing machines to

duplicate conditions of wearing."—C. L. Simon of Industrial By-Products Research Corp.

"The variation in abrasive materials is greater than the variation of textiles."—C. H. Masland

"Only by accumulating data on wear of fabrics which have been put into actual service will we be able to get anywhere."—R. O'Brien, U. S. Bureau of Home Economics

"Humidity and temperature are vitally important in testing wear resistance."—J. B. Quigg, Du Pont Rayon Co.

"The measurement of how much abrasion has taken place is a matter of laboratory test."—E. R. Schwarz, Massachusetts Institute of Technology

"In making tests, the moisture content of the specimen, rather than the relative humidity of the room, should be considered."—David Scott

"We should not make 'rubbing' synonymous with 'wear.'"—A. Sommaripa, Du Pont Rayon Co.

"To duplicate wear results, it is necessary to find out first what forces cause wear."—A. Ashcroft

"There should be an exhaustive study of present empirical wear-testing machines and then development of standard machines and methods for determining wear."—H. J. Ball, Lowell Textile Institute

"I should like to see fabrics classified as to use, the most important classes in which wearability is a factor grouped, the causes of wear determined, machines devised which duplicate service results, and properties of textiles which affect wearability determined."—H. DeWitt Smith, A. M. Tenney Associates

B—Test Machines and Apparatus

Chemical Abstracts

49. 1931, **25**, 2323[9]. **Abrasion test** on sole leather uses carborundum plate and weight equal to that of an average man on piece tested.

50. 1933, **27**, 2334[9]. **Wear resistance of sole leather.** Wear resistance is expressed as a fraction of that of a standard copper plate.

51. 1934, **28**, 6570[7]. **Wear on fabrics** is measured by rotating two small plates against each other, each covered with test material. A definite load may be used.

52. 1936, **30**, 2774[9]. **Apparatus to test wear resistance** by stress and friction is described in U. S. Patent 2,032,202.

53. 1937, **31**, 4511[1]. **Apparatus for testing wearing quality of fabrics** as described in U. S. Patent 2,078,259.

54. 1937, **31**, 4833[4]. **Apparatus for testing wearing quality of fabrics.** U. S. Patent 2,079,591. Has abrasive wheel with cleaner for debris.

55. 1939, **33**, 9036[9]. **Comparison of machines** testing resistance to abrasion. Tests show kind of abrasive used has more influence on results than the method of application.

56. 1941, **35**, 629[9]. **Determination of wearing qualities by air-flow measurements.** E. J. Saxl's article tells of measuring wear by use of a standard abrasion tester and a porosity tester. Method of showing correlation of wear and air permeability is given.

Journal of the Textile Institute

57. 1924, **15**, T230–6. **Wearing tests for yarns.** Rubbing apparatus uses a loom reed as a rubbing agent. It combines partial bending with scraping motion to test twenty parallel individual yarns to destruction in a preferredly vertical setup.

58. 1924, **13**, A116. **Abrasion tester.** Employs loose abrasive material with four rubbing units for samples and one for standard on a 130 r.p.m. rotating mandrel. Differences are measured by weighing and an index number is given for losses.

59. 1924, **15**, A345. **Wearing tester for German military cloth** consists of sample under tension being drawn back and forth over a knife until the cloth breaks. Mechanism records cycles.

60. 1929, **20**, A207. **Abrasion tester** controls the temperature, humidity, contact pressure, tension on fabric, rubbing rate, and direction while providing reciprocating motion. Serge used as abradant in testing lining material for coats. Rank in length of wear is: silk-cotton (1.0); crepe de Chine (0.7); and satin crepe poorest (0.5).

61. 1931, **22**, A413. **Schopper abrasion tester** has combined rotary and rolling motion instead of one-way friction.

62. 1932, **23**, T201. **Tensile strength, a limiting factor in wear.** Gurney and Davis worked with machine which has an oscillating comb which rubs on both sides of cloth at alternating positions. In the cycle of wear, stresses in the form of weights are

applied at both ends of the fabric so that in addition to abrasion, a variable stretch and partial release act on the surface as the cloth passes over the knife edges of the "comb." This is somewhat like the Amsler type of wear tester. It gives four types of wear: abrasion, stretch, variable stress (vibration), and bending.

63. 1933, **24**, A527. **Combined wearing and bursting tester,** made by L. Schopper in Germany, rubs against an abradant disc provided with a pneumatic device for exerting and measuring bursting pressure. Preliminary tests show rubbing cycles to fracture, and at two-thirds of the way to the limit the bursting mechanism is used, recorded, and indexed.

64. 1934, **25**, A304. **Fabric wear testing apparatus.** G. Cesconi in *Boll. R. Staz. Sper. Ind. Certa e Fibre Tess., Veg.*, 1934, **5**, 157–66, describes a machine which wears fabric in all directions variably by a planetary movement on a mushroom-shaped support. Wear is measured by loss in weight per unit time.

65. 1938, **29**, A45. **Fabric wearing quality testing machine.** A patent is described of machine which has a cylinder fitted with piston and rod with spring pressure. Strips of sample wear out by friction on rough circular disc. Stops automatically at break-through.

66. 1938, **29**, A169. **Fabric wear testing apparatus** has rotating abrasive-covered cylinder and another cylinder which has bronze blades. Amsler testing apparatus wears both surfaces of fabric with constant tension. May use moistened samples; it has some bad features, but comparisons are possible.

67. 1938, **29**, A765. **Measurement of wear and slippage resistance of fabrics.** Slippage of warp threads over weft often precedes failure of fabric in wear tests. The rubbing device is a wooden cone over which is stretched a piece of unbleached cotton fabric. Otherwise the apparatus is similar to the Muller type.

68. 1939, **30**, T133–6. **Improved abrasion tester.** (A modification and improvement on apparatus described in *Journal of the Textile Institute*, 1934, **25**, T134, by W. Davis.) He doubles number of rubs and places a hard ball opposite an inflated ball while rotating abraded sample to prevent parallel alignment of surface fibers, which would nullify abrasion in a short time. This wears quicker and better.

69. 1939, **30**, T172. **Improved abrasion tester.** Criticism of preceding article shows that results were of little value statistically, as they were too varying.

70. 1939, **30**, A125. **Round and flat wear testers.** Comparison by A. Heider in Klepsig's *Textil-Z.*, 1938, **41**, 618–23. Finds tester by Repenning to be better than Schopper Tester: has flat abrading surface, instead of curved surface which is less even in wear area.

71. 1939, **30**, A260. **Carpet wear testing machine** (Shawmut) has grooved disc abradant and automatic (periodic) thickness-measuring device. Pump sucks away dust.

72. 1939, **30**, A189. **Fabric testing apparatus.** Gives combined effects of resistance to rubbing, tensile strength, elasticity, and resistance to repeated bending. Fabric is so placed in opposing plates that it is stretched and bent to rub against itself. Compressed air blows off debris at opening. Automatic device stops at break in fabric and records strokes to time of break: this number represents quality. Method shows effects of wool quality and of injury in dyeing not shown in usual strength tests. This apparatus is described (under a patent) in the volume on page A264.

73. 1940, **31**, A398. **"Taber" abrasion testing machine.** In *Textile World*, 1940, **90**, 79–80. Machine has two abrasive wheels which rub sample on rotating disc. Result is to wear in all directions, back and forth and at angles of surface. Blowers prevent overheating and a recorder keeps number of revolutions.

74. 1942, **33**, T151–8. **New design of cloth wearing tester.** J. G. Martindale. Apparatus has means of rubbing abradant in a constantly changing direction over the cloth in the path of a "Lissajou's Figure" by starting as a circle, changing gradually to a straight line back and forth, approaching a circle again, and then slowly verging into a line traveling from side to side. Cloth is removed from plate at intervals for measurement by appearance, weight change, or other comparison. May vary figure of wear pattern to all linear motion. Wear is comparatively gentle and controllable; sample is easily replaced or tested.

Rayon Textile Monthly

75. 1936, **17**, 95 (April). **Shawmut wear testing machine** (Boston). Abrasive member is smooth and not affected by wear, temperature, or humidity changes. It has no manual adjustments for human errors, stops at predetermined period automatically.

has continuous oscillation and change of direction of abradant and sample while lifting periodically for tests of wear. Debris removed by vacuum.

76. 1937, **18**, 42 (November). **Eleven wear testers on market.** H. J. Ball of Lowell Textile Institute lists machines which test wear on fabrics: no descriptions are given, but addresses are included.

77. 1942, **23**, 70 (April). **New type tester** blows crushed stone compound at about 25 pounds per square inch pressure by means of a reducing valve (0 to 50). A spark plug cleaning machine and inexpensive abrasive are used to measure wear by time required to wear a hole in the fabric at constant pressure of blast.

Textile Colorist

78. 1942, **64**, 299. **New hosiery abrasion test machine** by U. S. Testing Co., Inc., wets sample by wick while abrading until formation of hole. This shows that many materials which are satisfactory to dry abrasion give poor results in wet rubbing.

TEXTILE RESEARCH (Abstracts)

79. 1939, **9**, 349. **New method of testing fabrics for abrasive wear.** German inventor has machine and method by which the three chief components of abrasion can be determined in a single operation. Refers to *Melliand Textilber.*, 1938, No. 11, pp. 899–901, which contains a description of the apparatus.

80. 1941, **11**, 373. **Abrasion tester** (*Canadian Journal of Research*, 1940, **18A**, 161–4). Abrasion testing machine has an automatically fed abrading surface in the form of a long tape supported by a revolving cylinder over which the fabric is rubbed back and forth. Power is shut off automatically and strokes are recorded when sample wears through.

81. 1941, **11**, 474. **Abrasion comparator** (*General Electric Review*, 1940, **43**, 467–70). Fabrics to be tested for wear resistance are wrapped around a square brass mandrel which is revolved inside a metallic washer which is laterally held in place in contact with the material. When fabric wears through electrical contact is made between the washer and the mandrel which is stopped by means of a low current relay. A reading is made of the number of revolutions required to wear through the fabric.

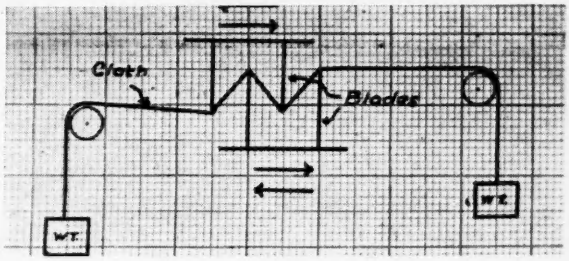

FIG. 2. *Diagram of principle of Amsler abrasion testing device.*

Textile World

82. 1926, **69**, 43 (April). **Abrasion tester.** A. J. Amsler of Switzerland has machine which bends, pulls, and abrades fabric by means of a combing device with cloth passing over alternate blades. 30 cycles/minute, reciprocating motion, wears out cloth. (See Figure 2.)

83. 1927, **72**, 83 (August). **Machine for determining the resistance of fabrics to external abrasion.** Made under supervision of E. R. Schwarz at Massachusetts Institute of Technology Textile Laboratory. Measuring the strokes of a bar covered with abradant as it passes to and fro for a distance of several inches over the fabric being tested. By controlling the weight on the bar and the speed of travel it is possible to wear samples uniformly enough to duplicate results quite closely. Device may be used as a standard test although it is not intended to imitate actual wear. Tensile strength tests are used in conjunction with this machine to compare results. The machine is more or less experimental and will be improved on. At that time the abradant decided upon was emery cloth. Forty strokes per minute were found satisfactory.

84. 1937, **87**, 2696 (December). **Portable fabric testing machine.** "Fidelity" tester stretches cloth over base plate and rubbing block respectively, giving lateral and transverse movements by cam control. It has motor power, a cycle counter with zero reset, removable weights, and weighs complete 110 pounds.

Country Homes for Research Laboratories

W. B. Foulk

Curator, Frick Laboratory, Princeton University

The following article will be of general interest because it illustrates the comparative ease with which a mansion can be converted to meet the requirements for a research laboratory or for educational purposes and because it typifies a movement, accelerated by wartime conditions, for the utilization of idle estates. It will be of special interest to the members of Textile Research Institute because it describes the alterations, now underway, to our building at Princeton which will make it into a modern laboratory devoted to fundamental research and to graduate training for textile scientists. The author, who is the Institute's building representative, has applied his expert knowledge and long experience in the design and maintenance of scientific laboratories to the planning and execution of the conversion task.

Of interest in recent years is the utilization of suburban estates, which, because of the smaller size of families and the increased cost of operating large homes, are no longer desirable as residences. Many of these large homes are ideally suited for institutional and educational purposes.

Several recent acquisitions of such properties for educational purposes are noteworthy—for example, the Harrison estate, known as "Grey Towers," which is now a part of Beaver College; the Mellon Mansion in Pittsburgh, now a part of the Pennsylvania College for Women; and the Manor House and adjacent buildings of the former Russell Estate at Princeton, New Jersey, which constitute the plant of the Edgerstoune Junior College.

An example of their use for research laboratories is that of Reynolds Metals, whose research activities are now housed on the Woolworth country estate. Another is the Institute of Textile Technology, which has acquired Boxwood, the former home of W. Alonzo Rinehart in Charlottesville, Virginia. Still other such projects are those of the Whitemarsh Research Laboratories of the Pennsylvania Salt Manufacturing Company, which are now located on the converted Stokesbury Estate at Chestnut Hill, outside Philadelphia, and the Textile Research Institute Laboratory, whose new home is the Baker Estate at Princeton.

The choice of these estates with their suburban location and their beautiful landscaped grounds is evidence of the increasing recognition of the advantages that obtain when fundamental research is pursued in quiet and pleasant surroundings. Moreover, the main buildings, which with one exception, are all of stone and reinforced concrete construction, could be converted into laboratoires with a moderate expense for alterations.

A further consideration, aside from the fact that the properties could be bought for a fraction of their original cost, was that it was possible immediately to set up laboratory facilities requiring a minimum of critical materials and put them into productive use for the war effort.

Of the projects with which the writer is familiar that of the Textile Research Institute is representative and will be described briefly. The considerations which prompted the choice of the Princeton property for the Textile Research Institute Laboratory were similar, and the problems encountered in planning and executing the conversion were, in at least one instance, almost parallel.

Two of the objectives of the Institute are to provide expanded laboratory facilities for the continuance of the fundamental research which has been carried on by the Textile Foundation for a number of years, and at the same time to provide an opportunity through fellowships for qualified young men to obtain graduate education in science which will prepare them for service in the textile industry.

This has been made possible through a coopera-

Fig. 1. *Textile Research Institute Laboratory at Princeton, N. J.*

tive arrangement with Princeton University whereby the Institute's fellowship students will pursue their academic work at the University and, upon fulfillment of the requirements of the Graduate College, receive their degrees from the University. The research investigations necessary for their experimental theses will be performed at the Textile Research Institute Laboratory. While the major emphasis will be placed on the study of fibers, the investigations will be fundamental in character and the problems will be broad in scope, in view of the need for textile scientists with superior training in the post-war period and of the acute shortage of them which is even now being experienced.

The Textile Research Institute Laboratory is situated on a promontory studded with large trees, which overlooks Lake Carnegie. It is set in from the public highway, so that it is sufficiently isolated to insure privacy, yet close enough to Princeton to be accessible. Thus the Laboratory personnel will not only have the use of the many facilities of the University, such as its scientific libraries, but will also receive the mental stimulus to be gained from contact with the University's faculty and scholars and other members of the "scientific community" which has grown so rapidly in Princeton in recent years.

When a building is being considered for conversion into a laboratory it is necessary to study the plans carefully in order to determine the maximum use to which it may be put at a minimum of expense for structural alteration, and to be sure that rooms will be of adequate size, and that the necessary mechanical services can be installed efficiently with respect to accessibility.

In the case of the Institute's Princeton building it was found that, with minor exceptions, alterations in the interior arrangement would be necessary in only two areas: the section of the first floor embracing the kitchen, pantries, and servants' living room; and the portion of the second floor occupied by the servants' bedrooms and bath. In most instances the changes involve simply the removal of partitions or the addition of a few new partitions. The Baker mansion contained numerous fireplaces. The flues from these are being utilized as ducts for the fume hoods, thus saving considerable material, labor, and expense.

The original house contained thirty-four rooms. After revisions it will contain thirty-three. However, area and room sizes in several intances have been increased by the removal of partitions. Much of this space was formerly occupied by porches, entries, and closets.

A hallway extends longitudinally almost the entire length of the basement, from a service entrance on the north side. There are ten rooms of various sizes opening from this hallway.

One of these rooms is being fitted up as a laboratory. Two others are being combined to provide a constant temperature and relative-humidity room. A third will house the air conditioned equipment. Others are devoted to a machine shop and storage and service rooms for the installation of mechanical

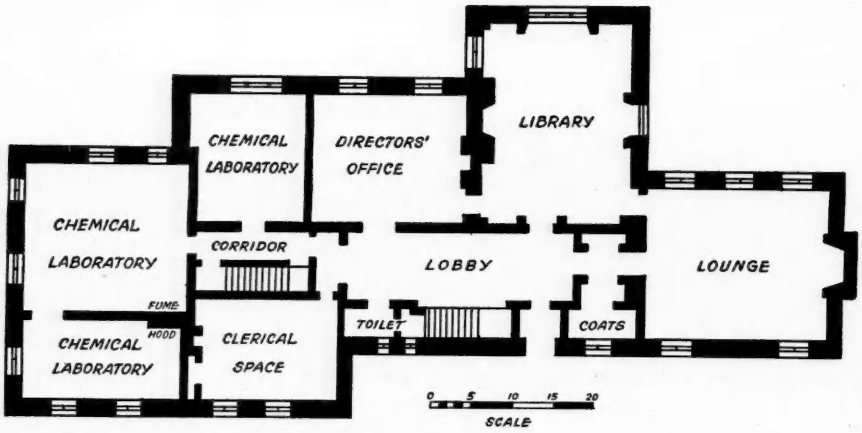

FIG. 2. *First-floor plan.*

service equipment. By the installation of automatically controlled oil-fired boilers, not only will the temperature in the rooms throughout the building be controlled within reasonable limits but hot-water generators, direct-current motor generators, switchboards, and similar equipment may be installed conveniently.

The rearrangement and utilization of the floor areas on the first and second floors are worthy of note. The lounge with its timbered ceiling and fireplace required little change for use as a combined common room and lecture room, except for suitable lighting and blackboard. The library as such is equally useful as an institutional library. The consideration here was to install and conceal waste and service piping required for the laboratory above without detracting from the architectural dignity of the room. The dining room that communicated with the library provides an office for the director and the study can be utilized as a clerical office with very little change.

Adjoining the former dining room was a serving pantry and a sunporch, both useless for laboratory purposes because of their size and location. By removing the partition between them a room 14 by 16 feet is being made which can be used as a laboratory. Units of two laboratory wall tables with an Alberene sink between are being installed on each side of the room. Provision is also made, by extending service pipes across the ceiling, for movable apparatus tables and other portable equipment to be used in the center of the room. Thus adequate accommodation for four chemists is obtained.

The area formerly occupied by the culinary section of the house was used to advantage by the removal of all partitions except the bearing wall containing the flues and, by enclosing the entrance to the porch, two laboratories are obtained which will provide adequate working space for seven chemists.

The north end of the second floor containing the servants' quarters required the most planning. However, by the removal of partitions and the erection of one new partition a large room is obtained and this also permitted the area formerly occupied by the servants' bathroom to be enlarged into a room of useful size. The fact that this bathroom contained only one small window became an asset rather than a liability by planning the room as a darkroom for experiments requiring either subdued light or total darkness. The alterations also permit the retention of the closet containing the housemaids' sink for janitorial use and provide an alcove for a water still. Minor alterations to another servant's room provide another laboratory in this section. Hoods are located in these rooms so as to take advantage of the flues as fume ducts.

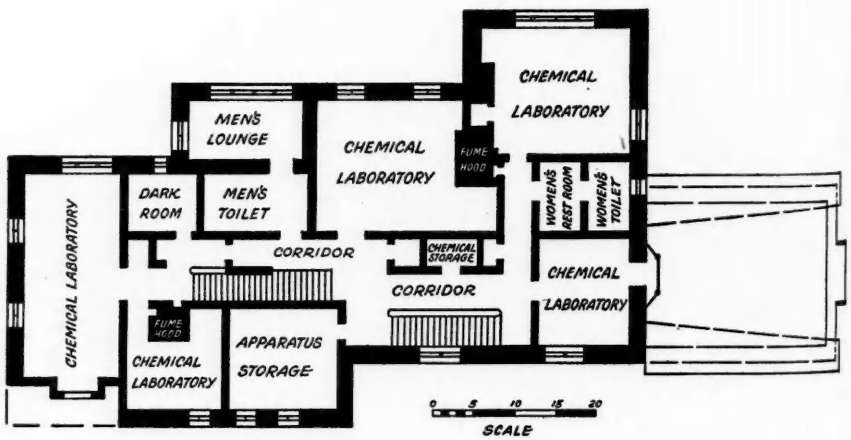

FIG. 3. *Second-floor plan.*

The master toilet is being converted to the men's lavatory and the enclosed sunporch beyond into a men's lounge. The master bedroom becomes a laboratory for two staff members and their assistants. The fume hood is located in front of the former fireplace, the flue to which affords a fume duct. Another former bedroom is being converted into a laboratory with fume hood, and an additional laboratory flanks the converted ladies' rest room and toilet. At the head of the staircase the former clothes' storage room is now an apparatus storeroom. Storage space for fine chemicals also is provided by the closets in the hallway.

The third floor required the least structural changes of any. Two of the bedrooms with a bath between remain unchanged at present, although provision has been made for extension of mechanical services to them should it be desirable to convert this area into laboratories in the future. They are useful as offices for staff members, particularly those interested in using the physical equipment such as spectrographs, spectrophotometers, and other optical instruments. A photographic darkroom has been provided by enlarging a clothes' closet and installing darkroom tables and other equipment. Another room previously used as a bathroom is being converted into an x-ray room with suitable power lines and water supply.

Steel laboratory furniture with Alberene stone tops, sinks, and drainboards was chosen because these materials are fireproof, durable, attractive in appearance, and, of even greater importance, it requires a minimum of maintenance. Because of the importance of these factors, specifications were drawn to insure construction that would eliminate crevices, exposed edges, and offsets that would trap corrosive fumes or would be difficult to get at to refinish if corrosion should occur. The order for laboratory equipment was given to a manufacturer whose experience, facilities, and reputation offered the best assurance that specifications would be followed, and whose furniture and method of construcure are among the best available at the present time.

The mechanical services provided to each laboratory consist of gas, hot and cold water, compressed air, direct and indirect current, and chemical waste lines. Other services that might be classed as luxuries, such as piping for vacuum, distillation, filtration, and other routine laboratory purposes, can be obtained by use of water suction pumps or by individual mechanical vacuum pumps, adequate provision having been made in all laboratories for their attachment and use.

It is believed that the completion of the conversion of the Institute building into a laboratory in accordance with the plans and specifications that have been developed and briefly outlined here will afford, in addition to library and clerical facilities, adequate laboratory facilities for twenty-four research workers for the type of investigations contemplated and at a moderate expense.

Textile Books Presented to Institute

The Textile Research Institute is pleased to announce the receipt of a gift of books from Douglas G. Woolf. This generous action by Mr. Woolf, who has assembled a selected collection of literature on textiles during his many years of active association with the industry, makes him the first donor of books to the Institute library.

Included in his gift of over 200 volumes are books on economics and on technology, some of which are now out of print and which it would therefore be difficult to replace.

ABSTRACTS

SERVICES AVAILABLE

Reprints of the original articles abstracted in TEXTILE RESEARCH JOURNAL *are often available from the publishers. Otherwise, it may be possible to secure copies of the periodicals. A list of periodicals, the abbreviations used in references to articles, and the addresses of publishers of English language publications was given on page 22 of the January, 1945, issue. Orders should be sent direct to the publishers.*

Photostat negatives of articles abstracted will be furnished to members of the Institute at a cost of 15 cents per page for pages not exceeding 7 inches in width and 25 cents per page for larger sizes up to 11½ x 14 inches. Postage will be added.

Microfilm copies and paper enlargements of microfilm may be obtained from: Microfilms Inc., 313 N. First St., Ann Arbor, Mich.; New York Public Library, New York, N. Y.; Yale University Library, New Haven, Conn.; Harvard University Library, Cambridge, Mass.; and Library of Congress, Washington, D. C. Translations may also be obtained from the above sources.

ANALYSIS: TESTING LABORATORY METHODS

★

Cellulose—Determination of Foreign Material

The gravimetric determination of foreign material in cellulose fibers. T. L. Rettger. *Oil and Soap* **22**, 7–10 (Jan. 1945).

A method is offered for the gravimetric determination of foreign material in cellulose fibers which is particularly applicable to cottonseed linters, fiber, and motes. The procedure is relatively simple and rapid, requiring only equipment and technique generally in use in the cottonseed industry's laboratories. Determinations are reproducible within significant limits. The foreign material, seed, hulls, hull bran, etc., is recovered (excepting particles finer than 50 mesh) so that it can be examined and classified as to type. The method involves treating the sample with fumes of hydrochloric acid to obtain the lint in a dry and brittle condition. The lint and foreign material are then separated by means of a series of screening operations.

E. G. M.

Analysis of Cellulose Esters

Analysis of cellulose derivatives. Carl J. Malm, Leo B. Genung, Robert F. Williams, Jr., and Mary Alice Pile. *Ind. Eng. Chem. Anal. Ed.* **16**, 501 (Aug. 1944).

Most saponification methods for the determination of total acyl in cellulose organic acid esters involve heterogeneous conditions. A method has been developed in which the sample is saponified in solution. As a result, homogeneous saponification conditions exist which eliminate errors due to the condition of the sample, improve the accuracy, shorten the time of saponification, and give a better end point. The effects of time, temperature, and alkalinity were studied and the optimum conditions for each were established. The range of applicability of this method is discussed and compared with the Eberstadt and alcoholic alkali methods. The basic principle followed involves solution of the sample in a suitable solvent, followed by stepwise additions of alkali and water under conditions such that the ester remains in solution until saponification is practically complete. The regenerated or only slightly esterified cellulose finally precipitates in a soft finely divided form which does not interfere with completion of the reaction or the back-titration. The precision obtainable by this method has been evaluated and limits of uncertainty (maximum range within which nearly all carefully run values should fall) are ±0.1 to 0.2% acetyl, depending on the type of ester being analyzed. A measure of the accuracy of the method was obtained by analyzing samples for free hydroxyl and for acetyl or apparent acetyl (saponification value calculated as acetyl) and complete acyl in the case of cellulose mixed esters. The observed acetyl or apparent acetyl values were compared with those calculated by difference from observed free hydroxyl contents and molar ratios of the acyl groups in the case of cellulose mixed esters, assuming exactly 3 hydroxyls per glucose unit of cellulose. The agreement was well within experimental error.

Author

Infra-Red Spectrometry

Small prism infra-red spectrometry. R. B. Barnes, R. S. McDonald, Van Z. Williams, and R. F. Kinnaird. *J. Applied Phys.* **16**, 77–86 (1945).

The small, general purpose infra-red spectrometer available commercially from the Perkin-Elmer Corporation (Model 12A) is described. The performance of the instrument with respect to theoretical and experimentally obtained resolution, relative merits of different prism materials, and the performance of the instrument chiefly for qualitative studies are discussed. Under ordinary laboratory conditions, it is possible to determine center of a sharp absorption band to ±2 $cm.^{-1}$ and to repeat to ±5 $cm.^{-1}$ with routine recordings. Absorption deflection repeats to ±5% under normal operating conditions; where higher precision is required the spectrometer may be set at a fixed wave length and transmissions measured to ±0.5% or better.

For 95% of work, slit widths of 5–7 cm.$^{-1}$ are adequate. Typical absorption curves are given. The spectrometer is intended as an inexpensive instrument for rapid analytical and exploratory work.

E. K. F.

Light Fastness

Testing dyed rayons for light fastness. Anon. *Can. Text. J.* **62**, 35 (Jan. 26, 1945).

Features of a new model Fadeometer used by the Ontario Research Foundation in its "Quality Control" testing laboratory are described and discussed. E. G. M.

Linen Fabrics—Measurement of Damage

Determination of damage in linen goods. Anon. *Text. Mercury and Argus* **111**, 468, 473, 475 (Nov. 3, 1944); 588–90 (Dec. 1, 1944); 666–8, 675 (Dec. 22, 1944).

The Solubility Number test has been widely used for testing the nature of linen. It involves first removing certain impurities in the linen by boiling it for six hours with a 2% solution of caustic soda, drying, and then determining the solubility of the residual cellulose in 8% caustic under standard conditions. The less damaged or degraded is the linen, the lower is its solubility. Pure undegraded linen will have a Solubility Number of 2 to 3, while for a linen which has suffered deterioration to a point which is definitely significant, this number will be 15 or more. The Copper Number test is more satisfactorily applied to cotton cellulose than to linen. Tests indicate that dimethyl-dibenzyl-ammonium hydroxide is more satisfactory for fluidity determinations on linen than is cuprammonium.

E. G. M.

Microscopy

Microscopy with light, electrons and x-rays. G. D. Preston. *J. Sci. Instruments* **21**, 205–13 (Dec. 1944).

The relation of the optics of light, x-ray, and electron microscopy is discussed, so as to allow a comparison of the methods, their differences, and their special advantages. 14 references.

pH Measurement

Colorimetric determination of the pH of liquids. Fr. Sierp and F. Fränsemeier. *Z. Ver. deut. Ing.* **1942**, 24; *Wasser u. Abwasser* **40**, 53 (1942) (through *Chem. Abstr.*, 1945, **39**, 1348^6).

A small apparatus is described by which pH values between 0.1 and 14 can be determined within 0.1 limit.

Refractive Index

The proportion of crystalline material in regenerated cellulose. P. H. Hermans. (Preliminary communication.) *Rec. Trav. Chim.* **63**, 13–24 (Jan., Feb. 1944) (in French) (through *Bull. Inst. Paper Chem.* **15**, 254).

Based on the observation that the specific birefringence of the ramie fiber is very nearly that of crystalline cellulose, one may calculate the birefringence which filaments regenerated from viscose would show if they were composed entirely of crystalline material. Since the birefringence actually observed is much weaker, it follows that these filaments contain only a certain fraction of crystalline material, in addition to a considerable portion of amorphous material, both of which contribute to the total birefringence. Whereas the experimental data do not permit the quantitative determination of the crystalline material present in the filaments, they do permit the fixation of an upper limit. Extrapolation to zero orientation fixes this limit for the isotropic state of the preparations studied to be between 20–30%. If one assumes with Kratky that the amount of crystalline material remains constant during the deformation procedure, its maximum would be of the same order of magnitude as that of the oriented filaments. If one considers, according to Wiener, the optical properties of cellulose to be those of a mixed binary system, the two components are anisotropic.

Textile Testing

The interpretation of laboratory tests as quality indices in textiles. A. G. Ashcroft. *Am. Dyestuff Reptr.* **33**, P486–9 (Nov. 20, 1944).

A change in emphasis in textile testing toward tests developed to measure length of service, maintenance of esthetic values, and desirableness is predicted. The need for conservative use of laboratory tests, used only in their legitimate spheres of research, standardization, and control, and for intelligent interpretation of test results, is stressed. Three basic types of quality which test procedures may be designed to measure are defined; suggested rules for scientific testing and a standard form for test method presentation are submitted. K. S. C.

CHEMICAL AND PHYSICAL RESEARCH

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Adsorption of Dyes

The combination of fibrous proteins with acids. II. The adsorption of dye anions. G. A. Gilbert. *Proc. Roy. Soc.* **183**, 167–81 (Nov. 1944).

Equations developed previously for the titration of fibrous proteins with acids are shown to accord with extant data for the adsorption of dyes in the presence of salt. The contribution of particular groups in the dye molecules to the free energy of adsorption is determined and the influence of the valency of the dye ion is related to the potential on the protein fiber. The effect of temperature on the ionic equilibria is calculated, and estimated experimentally for a simple dye using a rapid "null" method for the attainment of equilibrium. Author

Bobbin Drives

Kinematic errors in bobbin drives on roving frames. S. L. Gerhard. *J. Applied Phys.* **16**, 26–31 (Jan. 1945).

A method of determining the kinematic characteristics of a machine has been described, and it is shown how the results may be used to predict variations in the material being processed. As the material normally handled by the textile industry is noted for its non-uniformity statistical analysis must be used to interpret most of the data obtained. One of the major objectives of the industry is to study the sources of non-uniformity in an attempt to eliminate them. Therefore any clue toward a physically predictable pattern of variation is of value, for around this nucleus can be assembled a rational statistical analysis. Such an analysis can evaluate directly the seriousness of any such physical cause; this is in contrast to the necessarily empirical analysis that is the only recourse in the absence of physical theories.

Author

Cellulose Film

The optical anisotropy of cellulose film. Robert C. Gray. *J. Soc. Chem. Ind.* **63**, 241–5 (Aug. 1944).

The birefringence of cellulose film is found to be influenced by the pressure in the viscose at the moment of extrusion, by the rate of coagulation, and by the machine direction forces and the transverse frictional forces exerted on the film during the casting process; the relative retardation is unaffected by change of water content, but since increase of water content causes increase of thickness, it causes a corresponding reduction in birefringence. The birefringence has a minimum value B_0 at the middle of the web, and rises towards the selvedges in accordance with the Law: $B = B_0 + bx^4$, where x is the distance from the middle of the web, and b is a positive constant that depends on the transverse forces acting on the film during contraction. The dispersion of the birefringence follows the Law: $B = a - b/\lambda^2 + c/\lambda^4$, where a, b, and c are positive constants; B has a minimum value in the extreme red. For the same grade of film, the tensile strength in the machine direction, or in the transverse direction, is greater when the birefringence is greater. Stress in the machine direction can increase the permanent birefringence by 50%. Stress in the transverse direction can reduce the permanent birefringence to zero, and can reverse its sign; the final birefringence may be numerically as great as the initial birefringence. All commercial dyed cellulose films are dichroic, the effect being most pronounced in the chocolates and mauves. Author

Cellulose Viscosity

The influence of velocity gradient on the relation between viscosity and concentration in cuprammonium solutions of cellulose. W. James Lyons. *J. Chem. Phys.* **13**, 43–52 (Jan. 1945).

The numerous equations which have hitherto been employed to relate the viscosity of solutions of high polymers to the concentration of the solute have neglected to recognize explicitly the influence which velocity gradient (rate of shear) has upon the observed viscosity of non-Newtonian liquids. Consequently, the theoretically important intrinsic viscosity, calculated on the basis of these equations, from data obtained on a solution in the anomalous region is found to have a different value for each velocity gradient prevailing during measurement. A modification of the Baker-Philippoff equation has been developed empirically having the advantage that it yields a uniform value for the intrinsic viscosity of a given solution regardless of changes in velocity gradient. This new equation:

$$\eta_r = \left(1 + \frac{c}{\lambda}\right) + \left(k_i - \frac{8}{\lambda}\right)c$$

has been found to agree well with data on cuprammonium solutions of cellulose in concentrations below 0.5 g. per 100 ml. The parameter λ, interpreted as a function of velocity gradient, is found to increase with gradient, while k_i, which is shown to be the intrinsic viscosity η_i, is found to have a constant value characteristic of the solute. It appears that the second constant appearing in other recent equations, in addition to the intrinsic viscosity, may be interpreted as a velocity gradient adjustment term. The algebraic series into which the various recent equations can be expanded to express η_r are strikingly similar to each other and to a proposed equation based on the Eyring reaction-rate theory. Author

Enzymic Degradation of Starch

The constitution and enzymic degradation of starch and glycogen. Karl Myrbäck. *The Svedberg* (Mem. Vol.), 1944, 508–22 (in English); cf. *Svensk Kemi Tid.* 56, 60 (1944), and *C.A.* **37**, 4271[1] (through *Chem. Abstr.*, 1945, **39**, 1556[6]).

The formulations proposed by Haworth (*C.A.* **31**, 1371[6]) and Staudinger (*C.A.* **32**, 9050[2]) for the molecules of starch and glycogen do not bear a relation to any conceivable mechanism of the enzymic synthesis of polysaccharides. From the simplest assumptions of the mechanism of synthesis a formulation with multiple branching of the chains, similar to that proposed by Meyer (*C.A.* **37**, 6151[8]), has been developed. It is in very good agreement with the known facts concerning the enzymic degradation of polysaccharides and can give a quantitative interpretation of the facts.

Gas Fading

Action of the combustion products of illuminating gas at high concentration upon dyed cellulose rayon. A. M. Baron. *Teintex* **8**, 264–71 (1943). *Chem. Zentr.* 1943, II, 2265 (through *Chem. Abstr.* 1945, **39**, 816[7]).

A check on the work of Rowe and Chamberlain (cf. *Chem. Abstr.* **31**, 6887[2]). The combustion gases of a Bunsen burner are collected in a bell jar, cooled to 20°, and the specimens are exposed to these gases. The gas contains about 10.0 g. of S in 100 cu. m., mostly as CS_2. The gas contains approx. 3 g. of N oxide in 10 l. The dyes tested belong to the

anthraquinone and the azo group series. The action of the combustion gases largely agrees with the reaction of a soln. of HNO_2. Also N-bearing products, such as *p*-nitraniline scarlet, combine with the combustion gases with the formation of diazo compds. Many dyestuffs fade very badly under the influence of combustion gases and light, so that dihydroxy-ethylaminoanthraquinone goes from bright red to blue. Colors upon nylon do not fade.

Chemistry of Sulfite Process

Chemistry of sulfite cellulose cooking. Sixten Ulfsparre. *The Svedberg* (Mem. Vol.), 1944, 377–99 (through *Chem. Abstr.*, 1945, **39**, 1289[4]).

A general discussion, with about 90 references. Original data are given to show the importance of the final temperature and the CaO content on the yield of pulp and α-cellulose and the relation between the α-cellulose content of the resulting pulp and the viscosity. The yield of pulp increases by 5% for the same viscosity if the final temperature is increased from 130° to 150°; the yields decreased with an increased CaO content; thus, the same results are obtained by decreasing the CaO content of the cooking liquor or by increasing its temperature. More information is needed concerning the reactions of the cellulose and the changes in its molecular shape and the polydispersity, and the possibility of preparing pulps best suited for a particular technical purpose.

BLEACHING: DYEING FINISHING

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Dyeing with Vat Dyestuffs

Recent developments in the application of vat dyestuffs. Capt. R. S. Stribling. *Am. Dyestuff Reptr.* **34**, P99–103 (Feb. 26, 1945).

A very important stride in the development of dyeing with vat colors was brought about by the observation that the reduction of the vat colors to the "leuco" on a fabric can be accomplished completely in a matter of seconds at a temperature of 212° F, with uniform distribution of the soluble "leuco" throughout the textile material; the chemical stability of the dyestuff under these conditions is quite satisfactory. Recent technical developments have extended the application of vat dyes to wool, acetate and mixed-fiber fabrics. The fundamentals of the operation involve (1) pigment padding the vat color on the fabric, (2) drying, (3) re-padding the fabric with a solution of sodium hydrosulfite and caustic, plus an agent such as common salt or sodium formaldehyde sulfoxylate to suppress the migration of the color, (4) steaming the fabric for less than one minute at 212° F, (5) oxidizing, soaping and finishing as usual. All of the steps can be operated continuously; the only novel apparatus required is the steam chamber for step (4). During this steaming the vat color is reduced and the "leuco" derivative is penetrated thoroughly into the fabric and fixed. Results obtained are in every respect equal to the best conventional methods such as pigment-pad-jig application. It has been applied successfully to cotton fabrics of virtually every type; in certain modifications of the process small liquid developing baths ("boosters") may be used in conjunction with the steaming for color development. For example in dyeing cotton HBT the goods padded with reduced color are run into a closed chamber the upper portion of which is filled with atmospheric steam and the lower containing a reduction bath with soda ash as the alkaline medium; the goods are alternately immersed in the bath and exposed to the steam. No bleeding off of the color is obtained, and the volume of the booster is only one-sixth that employed in the ordinary continuous dyeing process; a further advantage is that the fabric requires very little preparation prior to dyeing. Similar modifications are described for use with Army terry toweling and numbered duck. It is expected that the pad-steam technique will find wide application in the dyeing of other classes of dyestuffs. Recent developments in the package dyeing of yarn with vat colors are also detailed. K. S. C.

Hosiery Finishing

Hosiery finishing. E. J. Siegrist. *Am. Dyestuff Reptr.* **34**, P88–90 (Feb. 26, 1945).

The more important finishing materials for hosiery are dulling agents, fillers, resins, rubber complexes, stiffeners, softeners and splash-proofing compounds. Of especial interest are rubber finishes, which may be widely developed after the war; resin emulsions having controllable substantivity (a very desirable property in any finishing compound) have been developed for nylon. The purpose in hosiery finishing is to improve serviceability as well as appearance; test methods for the former are discussed. It is stated that finishes which improve snag-resistance often adversely affect stretch and recoverability. An appeal is made for the development of hosiery finishes which may be applied before or during dyeing so that once the required shade is obtained it will not be subjected to the possibility of further change in finishing. K. S. C.

Indigo Dyeing

Continuous indigo dyeing of wool stock. W. Von Bergen, T. Crowley, and W. Brommelsieck. *Am. Dyestuff Reptr.* **34**, P53–62 (Jan. 29, 1945).

The factors leading to the development of continuous indigo dyeing of wool stock are described and the mechanical and chemical aspects of the process are explained in some detail. The propulsion of the wool stock through the bowls is accomplished by a series of parallel rakes operated from a cam governing the period of each sweep of the rakes; the motion is such as to minimize agitation which would introduce air tending to precipitate the indigo. The success of such a continuous process is stated to be dependent on the synchronized flow of both the material to be dyed and the dye liquor through the machine, as well as the efficient control of the accumulation of the various chemicals necessary in indigo dyeing. An investi-

gation of the several phases of the dyeing operation showed that (1) the depth of shade as specified by the Navy Department can be acquired by two dips of six minutes each; (2) the most favorable indigo concentration in the dye liquor is 3 grams per liter (dry indigo basis); (3) the dyed fiber maintains an indigo content of 7% through the final finishing operation, losing only about 0.5% in processing; (4) 60% of the dyeing is accomplished in the first dip and the remainder in the second dip; (5) when the oxidation products of the sodium hydrosulfite have built up to an equivalent of approximately 8 grams of oxygen per liter the effectiveness of the dye bath is terminated; (6) maintenance of a certain carbonate concentration is mandatory since without it bisulfite starts to accumulate; (7) the peroxide oxidizing bowl becomes inefficient after four hours running and should be dropped; (8) by very careful washing procedure and by treatment in the Derby dry-cleaning machine after shearing a crocking reflection of 80% (Munsell 8) was achieved. Three million pounds of wool stock have been dyed in the past 12 months by this method which has combined outstanding preservation of the wool fiber with high production efficiency. K. S. C.

FIBERS: YARNS: FABRICS MECHANICAL PROCESSES

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Fiber Impregnation

Effect of synthetic resins on cellulose and protein fibers. D. H. Powers. *Ind. Eng. Chem.* **37**, 188–93 (Feb. 1945).

When cellulose fibers are impregnated with resin-forming solutions of unpolymerized urea-formaldehyde, melamine-formaldehyde, or phenol-formaldehyde, these resin formers have little effect on the properties of the fibers until the resins are cured or polymerized within the fiber. Evidence shows that the resin is uniformly distributed through the fiber and, in certain cases, may actually react within the cellulose. Low concentrations of the resins formed within the fiber have pronounced effects on the physical properties, changing the elongation, elasticity, wet strength, moisture regain, resilience, and dyeing properties. A new method of determining the degree of resin polymerization has been developed. It is also shown that wool and protein fibers may be impregnated with resin-forming solutions; however, there is no evidence that they react with the wool protein. The medium in which the resin-forming materials are applied has a tremendous effect on the properties obtained, and it is shown that fiber swelling is necessary to insure thorough penetration. Electron photomicrographs are shown of treated and untreated fibers. Author

Fiber Structure

Textile fibers. W. Astbury. *Silk J. Ray. World* **21**, 37–8 (Feb. 1945).

An address pointing out the position of scientists as leaders in the textile field in recent years and their opportunities in the future. The value of x-ray studies in determining fiber structure is emphasized. E. G. M.

Loom Research

Weaving machine research. Albert Palmer. *Am. Wool and Cotton Reptr.* **59**, 165, 169, 171, 173 (Feb. 8, 1945).

An ingenious electric picking motion is described, and improvements in this motion by means classified as pneumatic, mechanical, and hydraulic are referred to. Excessive cost holds up the incorporation of these improvements. High-speed camera studies are described.

H. J. Burnham

Progress in the Production of Cotton

Developments in cotton quality testing as related to breeding, harvesting, ginning, and marketing. Frances L. Gerdes. Bulletin issued by War Food Administration, Office of Marketing Services, Cotton and Fiber Branch, U. S. Department of Agriculture.

Progress in the improvement of the quality of cotton and in the lowering of cost of production is described. The adoption of scientific laboratory methods and facilities for making accurate and practical measurements of cotton quality through fiber and spinning tests on small samples has speeded improvements in cotton breeding, and cotton is being bred for specific uses. Widespread improvements are being made in gin machinery and operating practices, some of which are described. Attention is being given to the development of more economical methods of harvesting. It is shown that cotton drying at the gins has been effective in bringing about improvements in the grade. Mechanical picking is discussed and it is concluded that the successful adaptation of mechanical harvesting is likely to depend upon the development of equipment for the extraction of extraneous matter from the ginned lint after its separation from the seed and before pressing into bales at the gins. Research directed to the development of such equipment is now under way at the U. S. Cotton Ginning Laboratory. J.

Rayon Sizing

Developments in rayon sizing operations. A. G. Arend. *Silk J. Ray. World* **20**, 33–4, 39 (Sept. 1944).

A brief review of the technology of rayon slashing. A. R. M.

Rayon Staple Spinning

Modern rayon staple spinning methods and equipment. R. J. McConnell. *Can. Text. J.* **62**, 34, 36, 44, 46 (Feb. 9, 1945).

A discussion of opening and picking, carding, drawing and fly-frame, and spinning equipment specially designed for handling long fibers and producing various types of blend yarns. E. G. M.

Speed Control in Cloth Drying

Automatic speed control on cloth drying machines. K. S. Laurie. *Silk and Rayon* **18**, 1332–3 (Dec. 1944).

A discussion of the advantages of the "Dalglish Automatic Speed Control" for bringing fabrics off the drying machine in a correct and even condition of moisture. The author states that by its use the speed of the cloth travel is continuously and automatically controlled to bring the cloth off in a constant state, regardless of the variation in the initial moisture content and various other factors affecting drying. E. G. M.

New Synthetics

A review of progress in processing and production. Anon. *Silk J. and Ray. World* **21**, 22–4 (Feb. 1945).

A review of the principal English patents in the development of synthetics during 1944. Synthetic fibers covered by these are: nylon, vinyon, saran, acetate rayon, Fortisan, Lanese, Rayolanda, Lanital, Aralac, soybean rayon, alginate rayon. Also emphasized are developments in viscose rayon dyeing and in the arresting of laddering in rayon hose. E. G. M.

Tire Cords

Tire cords—cotton and rayon. A. Scholes. *J. Text. Inst.* **35**, P99–113 (Oct. 1944).

There has been no scientific information published, for obvious reasons, comparing the performances of rayon or cotton cords in similar tires running under similar conditions. It is known generally that the U.S.A. production of rayon yarn for tire cords has been increased to 240,000,000 lbs. and that rayon is being used in ever increasing quantities in England. Presumably there is sound reason behind this, but there is no doubt that the substitution of synthetic rubber G.R.S. is partly responsible. The information in this paper deals only with the behavior of cords and fibers, and there seems evidence to show that rayon is superior to cotton. The future should be interesting. Technical improvements in rayon and cotton are bound to follow as soon as we know precisely what are the relevant factors dominating the life and durability of a tire. With the limited facilities at present available to British rayon spinners, much creditable progress has been made, and more will certainly be made in the future. The tire-cord twisters of Lancashire have developed rayon splendidly and will continue to improve their cotton cords. Research on cotton and rayon is necessary and cooperation between the spinners, twisters and tire manufacturers is essential. Standardization of testing is already overdue, and although this has been tentatively discussed, no real progress is forthcoming. The relative importance of rayon and cotton in the future is difficult to assess. It is certain that rayon has come to stay and no doubt financial considerations are important. We can speculate on natural and synthetic rubber, cheaper rayon and cheaper cotton, but no one will be able to be certain until the essential technical knowledge has been gained in order to form a sound basis for healthy commercial competition. Author

Water-Repellent Treatments

Water impedient treatment and retreatment of clothing fabrics. Lt. G. P. Fulton, SC, USNR. *Am. Dyestuff Reptr.* **34**, P95–8 (Feb. 26, 1945).

The action of laundering and dry-cleaning on the several types of water-repellent treatments is discussed; methods of retreatment from aqueous and organic solvent systems are described. Impurities such as soap, wetting agents and hygroscopic inorganic salts detract from the hydrophobic character of the treated material. Thus some Navy garments require water rinsing to remove sea water salts before water-repellent retreatment in an organic solvent bath. The effect of fabric construction on water repellency is considered; by lowering the twist in Navy jungle cloth the resistance to water penetration was increased several times. K. S. C.

MISCELLANEOUS

★

Status of the Textile Chemist

The professional and economic status of the textile chemist. Andrew Fraser, Jr. *Am. Dyestuff Reptr.* **34**, P10–13 (Jan. 1, 1945).

The relative standing of the textile chemist with respect to years of experience and earning capacity is shown by means of data from the 1940 Census and from the 1941 and 1944 Surveys of the Economic Status of the Members of the American Chemical Society. The demand for textile chemists from 1926 to 1943 increased markedly, and their employment opportunities remain substantial in number and broad in extent. The earnings capacity of textile chemists ranks high contrasted with that of other chemists.

K. S. C.

Damage by Insects

Destruction of paper and books by insects and means of fighting them. L. G. E. Kalshoven. *Pharm. Tijdschr. Nederland Indië* **18**, 143–64 (1941) (through *Chem. Abstr.*, 1945, **39**, 1482[7]).

The destruction of paper and particularly of books in the tropics by termites, silverfish, bookworms, other insects, and rats and means of combating this destruction by the proper construction of shelving in a dry atmosphere, the use of varnishes, and of chemicals, e.g., $C_{10}H_8$, $HgCl_2$, phenols, As_2O_3, CH_2O, $C_6H_4Cl_2$, NaF, etc., are discussed.

Dielectric Heating

Application of dielectric measurements to cellulose and cellulose-filled phenolic laminating materials. Thomas W. Dakin and R. W. Auxier. *Ind. Eng. Chem.* **37**, 268 (1945).

The principles of dielectric heating and methods of dielectric measurements are reviewed. Measurements of dielectric constant and dissipation factor in the radio frequency range are presented for cotton duck, kraft

paper, and alpha paper, impregnated and unimpregnated with cresylic and phenolic resins. The effect of moisture content between 2.7 and 13.3% and of frequency between 1 and 50 million cycles per second is given. The manner in which such dielectric data may be used in heating applications and major problems of application are discussed. R. H. Wilhelm

Principal limitations of dielectric heating. Carl J. Madsen. *Rubber Age* **57**, 66 (1945).

The characteristics, advantages, and limitations of dielectric heating of rubber and plastics are reviewed. Cost, and material and electrical considerations such as dimensions and type of material, frequency, voltage and loss factor are mentioned. A cost figure of $0.025 to $0.04 per kw. hr., including direct operating cost, maintenance and amortization, is given. Special advantages which may lead to satisfactory economy are listed. Warning is given that dielectric heating is not universal in application and that careful analysis is required to determine suitability.
R. H. Wilhelm

Melamine Resins

Melamine and melamine resins. John Olsson. *The Svedberg* (Mem. Vol.), 1944, 344–51 (through *Chem. Abstr.*, 1945, **39**, 1319[5]).

A description of the chemistry, production, and applications of melamines. 15 references.

Mill Construction

Planning the construction of your postwar mill. James Osborne. *Textile Age* **9**, 84, 86, 88 (Mar. 1945).

The third of a series. This article discusses ceiling height, column spacing, long span construction, windows, glass blocks, and construction cost. It is estimated that a modern one-story building suitable for spinning and weaving can be built at a cost ranging from $4.00 to $4.50 per square foot.
H. J. Burnham

Mill Modernization

Mill modernization and possible developments. Anon. *Am. Wool and Cotton Reptr.* **59**, 49, 51, 53, 55 (Apr. 12, 1945).

Important recent improvements in handling filament rayon fabrics will be protection from competition, but staple fiber has more problems. Many changes are needed in cotton processing and in woolen and worsted manufacturing. H. J. Burnham

Textile Production

Textile production in 1944 and outlook for this year. Anon. *Am. Wool and Cotton Reptr.* **59**, 19–20 (Feb. 8, 1945).

Cotton goods output declined while military requirements increased. Wool fabrics production was about the same as in 1943. Rayon yardage showed slight increase. Military requirements took 22% of the total cotton cloth production, 25% of the wool, and 6% of the rayon fabric in 1944. Civilian supply of wool and rayon cloth will be short this year, but only in cotton is the shortage expected to be serious.
H. J. Burnham

Textile Technology Institute

Textile Technology Institute building. Anon. *Am. Wool and Cotton Reptr.* **59**, 77, 79, 81 (Apr. 12, 1945).

An announcement of the building program of the Institute of Textile Technology, a graduate school chartered by the state of Virginia, recently approved by the board of trustees. Fifteen acres are now owned by the Institute. The chief function of the research section will be the application of fundamental and technical developments to commercial size textile machinery.
H. J. Burnham

Toxicity of Waste Matter

Effect of waste water from cellulose-manufacturing industries on fish. H. Liebmann. *Angew. Chem.* **54**, 499–500 (1941); *Wasser u. Abwasser* **40**, 61–2 (1942) (through *Chem. Abstr.*, 1945, **39**, 1490[5]).

Direct poisoning action was observed only in concentrated wastes or waste from sulfate cellulose plants. Indirect harm was caused by reduction in O content, poisonous action of H_2S, and fungus growth (through further O consumption in the decomposition of dead material). Waste should never be discharged into quiet water, and even in flowing water it creates zones poor in plant and animal life. There is no waste water from the wood-sugar industry unless fermentation to alcohol and production of fodder yeast are undertaken. In the latter cases the $KMnO_4$ consumption may be as high as 20,000 mg. per 1. From the standpoint of the waste water, the Bergius process is to be preferred, as the HCl is recovered. In the Scholler process, where the H_2SO_4 is not recovered, there are more impurities in the waste water.

Wool Market

Wool market reviewed for year 1944. Anon. *Am. Wool and Cotton Reptr.* **59**, 67, 69, 71–3, 75 (Feb. 8, 1945).

A review of the wool situation during the past year as regards consumption and availability of the various types. H. J. Burnham

Warp-Knitting Machine

New British warp-knitting machine. Anon. *Silk and Rayon* **18**, 1324–5 (Dec. 1944).

A description of a British warp-knitting machine which, knitting at more than twice the rate of other machines, breaks previous speed records yet produces ladder proof rayon fabric of high quality. It is claimed that this warp-knitting machine makes over 2,350,000 loops per minute with such precision that over long periods of operation not a single loop is faulty. When running at 1,000 courses per minute the absence of vibration and noise is impressive. The operating speed is 1,000 r.p.m. The production rate is 30 yds. per hour. It is claimed that on an average only one thread breaks per 100 yds. of cloth produced. E. G. M.